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FUNDAMENTALS OF SHOPWORK

A PRE-INDUCTION COURSE AT THE FOUNDATIONAL LEVEL

LONDON
E. & F. N. SPON Ltd.,
57 Haymarket, S. W. 1
1945

Printed in the United States of America

Preface

e War Department, knowing the importance of vocational
ses in the training of those who are about to be inducted into
rmed Forces, is urging potential inductees to take courses
opwork, electricity, and machines in school or by home study.
Army wants every soldier to be so trained as to reduce to a
num the number of casualties. It expects every soldier to
tain his equipment, whether it is a gun or a vehicle. Nat-
y, the soldier who has had some mechanical training before
tion has the advantage over the one whose training has been
y academic.

careful study of Army occupations revealed that a knowledge
op theory and practice contributes to good work in 188 Army
(A knowledge of machines, by the way, helps in 226 Army
a knowledge of electricity, in 151.) Like its companion
s, Dull and Newlin's *Fundamentals of Machines* and Dull and
n's *Fundamentals of Electricity*, this book has been developed
request of the War Department and the U. S. Office of
ation. *Fundamentals of Shopwork* conforms to the pre-
tions of the War Department's outline, *PIT-103, Pre-
ction Training Course in Fundamentals of Shopwork: A Basic
se.*

e fact that *Fundamentals of Shopwork* was constructed ac-
ng to War Department specifications for a pre-induction
ing course does not, however, limit the book's usefulness to
ration for military service. The mechanical skills needed by
rmed Forces are almost always the same as those needed by
stry. The fundamentals of the various shopwork trades are
od deal alike. A carpenter must know how to use a screw-

driver; so must a machinist. A radio mechanic must know flu and solders; so must a sheet-metal worker. *Fundamental Shopwork* develops the understandings leading to operational s basic not only to 188 Army jobs but also to a far greater nur of industrial jobs — sheet-metal workers, aircraft-instrument cialists, aircraft and engine mechanics, automotive mecha construction carpenters, ship's carpenters, telephone and graph linemen, bridge builders — a list of industrial occupat too long to catalog here. Our point is that this book will s as well for pre-industrial as for pre-induction training.

And it will serve as well for home study as for classroom u The authors have "put the teacher into the textbook" in ev possible way.

As a classroom tool, *Fundamentals of Shopwork* can be used two ways. Schools which have shops in which pupils can car out the suggested projects will find this book an effective aid learning and a handy reference. Schools which have no sho and cannot set them up during wartime, can use this book as basic textbook in shop theory and practice, needing only a ve few of the simplest and most common tools. It is not necessa to have a fully equipped shop to give the course. This is a cou *to develop the understandings that lead to operational skills.* In t sense it is a pre-vocational rather than a strictly vocational cour The student who goes from *Fundamentals of Shopwork* to sh training in one of the Armed Forces or in industry will have great advantage over the untrained beginner. He will know wh he is doing, why, and with what tools. He will not have to lea the language of the shop as he goes along. Certain natural erro in planing, soldering, and grinding or sharpening tools will hav been pointed out to him. The major part of his attention can b spent on getting manual skill and confidence.

In *Fundamentals of Shopwork*, every technical term or expressio peculiar to shopwork is carefully explained. Vocabulary has bee checked to make sure that it is easily understandable by fou teen- and fifteen-year-olds; yet the language here and the sty of writing will sustain adult interest. Processes are explaine rough a progressive-step arrangement supplemented wherever essary by illustrations. Most of the illustrations are clear drawings. Much use has been made of the motion-picture form illustrating complicated processes — each step of a process wn in a separate drawing. There are also photographs, many hem taken especially for this book.

Vherever shopmen disagreed about a particular procedure, the hors went directly to industry to find the best practice. If o or more methods of about equal value are used in shops, are treated here. A good deal of related information, not ually called for by *PIT–103*, has been presented in order to und out certain topics.

The content is thoroughly cross-indexed. If the same topic ust be touched upon in several places, its full development is ven at the most appropriate point, and summaries from other ngles are given at other points; but wherever this topic appears, erence is always made to the point of its full development.

At the end of each unit are a summary, a series of review ques- ons, student activities, and a short examination of a new ype.

Instructions are complete for the proper care, conditioning, e, and storage of tools. The authors have emphasized good fety practices. Proper care of tools and high regard for safety — e's own and that of others — have always been marks of the ood workman, and today they are definitely in the national in- erest. Special instructions for emergency repairing of tools and quipment are included for the men who, in the Armed Forces or lsewhere, may find themselves far away from a well-equipped hop.

To sum up the uses to which *Fundamentals of Shopwork* can be ut: first, it will serve as a pre-induction training textbook, in lassroom or home study; second, it will improve the beginner's kills in industry, whether studied in class or at home; third, it ill prove a valuable survey and book of reference for shop ourses in schools which have abundant shop equipment; fourth, will support a strong course in shop theory and practice in schools which have no shop equipment. This may be a likely place in which to state the authors' hope that shopwork may be added more generally, during and after the war, to academic curricula. All students will profit from knowing how to work with their hands as well as with their brains.

D. J. S.
July, 1943
M. J. G.
A. L.

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SUPPLEMENTARY TABLES
OF
BRITISH STANDARD SIZES

TABLE 1.—SUPPLEMENTARY TO TABLES 8 AND 10 OF APPENDIX A

WOOD SCREWS AND BORING SIZES

Screw Gauge No	Diam of Shank Inches	Clearance Hole Inches	Pilot Hole		Length Overall															
			Hardwood Inches	Softwood Inches	$\frac{1}{4}$″	$\frac{3}{8}$″	$\frac{1}{2}$″	$\frac{5}{8}$″	$\frac{3}{4}$″	$\frac{7}{8}$″	1″	$1\frac{1}{4}$″	$1\frac{1}{2}$″	$1\frac{3}{4}$″	2″	$2\frac{1}{4}$″	$2\frac{1}{2}$″	$2\frac{3}{4}$″	3″	$3\frac{1}{2}$″	4″
1	066	$\frac{5}{64}$	$\frac{1}{32}$	$\frac{1}{32}$	x	x	x	x													
2	080	$\frac{3}{32}$	$\frac{3}{64}$	$\frac{1}{32}$	x	x	x	x													
3	094	$\frac{7}{64}$	$\frac{1}{16}$	$\frac{3}{64}$	x	x	x	x													
4	108	$\frac{7}{64}$	$\frac{1}{16}$	$\frac{3}{64}$	x	x	x	x	x	x	x										
5	122	$\frac{1}{8}$	$\frac{5}{64}$	$\frac{1}{16}$	x	x	x	x	x	x	x										
6	136	$\frac{9}{64}$	$\frac{5}{64}$	$\frac{1}{16}$	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
7	150	$\frac{5}{32}$	$\frac{3}{32}$	$\frac{1}{16}$		x	x	x	x	x	x	x	x	x	x	x	x	x	x		
8	164	$\frac{11}{64}$	$\frac{3}{32}$	$\frac{5}{64}$		x	x	x	x	x	x	x	x	x	x	x	x	x	x		
9	178	$\frac{3}{16}$	$\frac{7}{64}$	$\frac{5}{64}$		x	x	x	x	x	x	x	x	x	x	x	x	x	x		
10	192	$\frac{3}{16}$	$\frac{7}{64}$	$\frac{3}{32}$		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
11	206	$\frac{13}{64}$	$\frac{1}{8}$	$\frac{3}{32}$			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
12	220	$\frac{7}{32}$	$\frac{1}{8}$	$\frac{7}{64}$			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
13	234	$\frac{15}{64}$	$\frac{9}{64}$	$\frac{7}{64}$						x	x	x	x	x	x	x	x	x	x	x	x
14	248	$\frac{1}{4}$	$\frac{9}{64}$	$\frac{7}{64}$						x	x	x	x	x	x	x	x	x	x	x	x
16	276	$\frac{17}{64}$	$\frac{5}{32}$	$\frac{9}{64}$						x	x	x	x	x	x	x	x	x	x	x	x
18	304	$\frac{19}{64}$	$\frac{3}{16}$	$\frac{9}{64}$						x	x	x	x	x	x	x	x	x	x	x	x
20	332	$\frac{21}{64}$	$\frac{13}{64}$	$\frac{11}{64}$						x	x	x	x	x	x	x	x	x	x	x	x
22	360	$\frac{23}{64}$	$\frac{7}{32}$	$\frac{11}{64}$										x	x	x	x	x	x	x	x
24	388	$\frac{3}{8}$	$\frac{7}{32}$	$\frac{3}{16}$										x	x	x	x	x	x	x	x

TABLE 2

SUPPLEMENTARY TO TABLE 9 OF APPENDIX A

WIRE AND SHEET GAUGES

NOTE.—Standard Wire Gauge (S.W.G.), also known as the Imperial Wire Gauge, is used almost exclusively in the United Kingdom for wires.

Birmingham Gauge (B.G.) was legalised by an Order in Council as from 1st November, 1914, for iron and steel sheets and hoops.

Special gauges are used for Zinc and many of the older gauges are perpetuated locally.

Decimal Inches	S.W.G.	B.G.	Decimal Inches	S.W.G.	B.G.	Decimal Inches	S.W.G.	B.G.	Decimal Inches	S.W.G.	B.G.
1·0000		15/0	0·1764		7	0·02476		24	0·0043		39
0·9583		14/0	0·176	7		0·024	23		0·0040	42	
0·9167		13/0	0·160	8		0·02204		25	0·00386		40
0·8750		12/0	0·1570		8	0·022	24		0·0036	43	
0·8333		11/0	0·144	9		0·020	25		0·00343		41
0·7917		10/0	0·1398		9	0·01961		26	0·0032	44	
0·750		9/0	0·128	10		0·018	26		0·00306		42
0·7083		8/0	0·1250		10	0·01745		27	0·0028	45	
0·6666		7/0	0·116	11		0·0164	27		0·00272		43
0·625		6/0	0·1113		11	0·015625		28	0·00242		44
0·5883		5/0	0·104	12		0·0148	28		0·0024	46	
0·5416		4/0	0·0991		12	0·0139		29	0·00215		45
0·500	7/0	3/0	0·092	13		0·0136	29		0·0020	47	
0·464	6/0		0·0882		13	0·0124	30		0·00192		46
0·4452		2/0	0·080	14		0·0123		30	0·00170		47
0·432	5/0		0·0785		14	0·0116	31		0·0016	48	
0·400	4/0		0·072	15		0·0110		31	0·00152		48
0·3964		1/0	0·0699		15	0·0108	32		0·00135		49
0·372	3/0		0·064	16		0·0100	33		0·00120	49	50
0·3532		1	0·0625		16	0·0098		32	0·00107		51
0·348	2/0		0·056	17		0·0092	34		0·0010	50	
0·324	0		0·0556		17	0·0087		33	0·00095		52
0·3147		2	0·0495		18	0·0084	35				
0·300	1		0·048	18		0·0077		34			
0·2804		3	0·0440		19	0·0076	36				
0·276	2		0·040	19		0·0069		35			
0·252	3		0·0392		20	0·0068	37				
0·250		4	0·036	20		0·0061		36			
0·232	4		0·0349		21	0·0060	38				
0·2225		5	0·032	21		0·0054		37			
0·212	5		0·03125		22	0·0052	39				
0·1981		6	0·028	22		0·0048	40	38			
0·192	6		0·02782		23	0·0044	41				

TABLE 3

SUPPLEMENTARY TO TABLE 11 OF APPENDIX A

BRITISH STANDARD WHITWORTH SCREW THREADS (B S W.)

Full Diameter Inches	Core Diameter Inches	Threads per Inch	Tapping Drill Size	Clearance Drill Size
$\frac{1}{16}$	0412	60	No 56	No 52
$\frac{3}{32}$	0671	48	,, 50	,, 41
$\frac{1}{8}$	0930	40	,, 40	,, 30
$\frac{5}{32}$	1163	32	,, 31	,, 22
$\frac{3}{16}$	1341	24	,, 28	,, 12
$\frac{7}{32}$	1654	24	, 18	,, 2
$\frac{1}{4}$	1860	20	,, 10	Letter F
$\frac{5}{16}$	2414	18	Letter E	,, O
$\frac{3}{8}$	2950	16	,, N	,, V
$\frac{7}{16}$	3460	14	,, T	$\frac{29}{64}$″
$\frac{1}{2}$	3933	12	,, X	$\frac{33}{64}$″
$\frac{9}{16}$	4558	12	$\frac{15}{32}$″	$\frac{37}{64}$″
$\frac{5}{8}$	5086	11	$\frac{33}{64}$″	$\frac{41}{64}$″
$\frac{11}{16}$	57111	11	$\frac{37}{64}$″	$\frac{45}{64}$″
$\frac{3}{4}$	6219	10	$\frac{41}{64}$″	$\frac{49}{64}$″
$\frac{13}{16}$	6844	10	$\frac{45}{64}$″	$\frac{53}{64}$″
$\frac{7}{8}$	7327	9	$\frac{3}{4}$″	$\frac{57}{64}$″
1	8399	8	$\frac{55}{64}$″	$1\frac{1}{64}$″

TABLE 4

SUPPLEMENTARY TO TABLE 11 OF APPENDIX A

BRITISH STANDARD FINE SCREW THREADS (B.S.F.)

Full Diameter Inches	Core Diameter Inches	Threads per Inch	Tapping Drill Size
$\frac{7}{32}$	·1731	28	No 16
$\frac{1}{4}$	·2007	26	,, 5
$\frac{9}{32}$	·2320	26	Letter B
$\frac{5}{16}$	·2543	22	,, G
$\frac{3}{8}$	·3110	20	,, O
$\frac{7}{16}$	·3664	18	—
$\frac{1}{2}$	·4200	16	$\frac{27}{64}$″
$\frac{9}{16}$	·4825	16	$\frac{31}{64}$′
$\frac{5}{8}$	·5335	14	$\frac{35}{64}$″
$\frac{11}{16}$	·5960	14	$\frac{39}{64}$″
$\frac{3}{4}$	6433	12	$\frac{21}{32}$″
$\frac{13}{16}$	·7060	12	$\frac{23}{32}$″
$\frac{7}{8}$	·7586	11	$\frac{49}{64}$″
1	·8719	10	$\frac{7}{8}$′
$1\frac{1}{8}$	·9827	9	1″
$1\frac{1}{4}$	1·1077	9	—
$1\frac{3}{8}$	1·2149	8	—
$1\frac{1}{2}$	1·3399	8	-
$1\frac{5}{8}$	1·4649	8	—
$1\frac{3}{4}$	1·5670	7	- -
2	1·8170	7	—
$2\frac{1}{4}$	2·0366	6	—
$2\frac{1}{2}$	2·2866	6	-
$2\frac{3}{4}$	2·5366	5	-
3	2·7439	5	-

TABLE 5

SUPPLEMENTARY TO TABLE 11 OF APPENDIX A

BRITISH STANDARD PIPE SCREW THREADS (B.S.P.)

Nominal Bore of Pipe Inches	Overall Diameter of Thread Inches	Core Diameter Inches	Threads per Inch
⅛	0·383	0·337	28
¼	0·518	0·451	19
⅜	0·656	0·589	19
½	0 825	0·734	14
⅝	0·902	0·811	14
¾	1·041	0·950	14
⅞	1·189	1·098	14
1	1·309	1·193	11
1¼	1·650	1·534	11
1½	1·882	1·766	11
1¾	2·116	2·000	11
2	2·347	2·231	11
2¼	2·587	2·471	11
2½	2·96	2·844	11
2¾	3·21	3·094	11
3	3·46	3·344	11
3¼	3·70	3·584	11
3½	3·95	3·834	11
3¾	4·20	4·084	11
4	4·45	4·334	11
4½	4·95	4·834	11
5	5·45	5·334	11
5½	5·95	5·834	11
6	6·45	6·334	11

TABLE 6

SUPPLEMENTARY TO TABLE 11 OF APPENDIX A

BRITISH ASSOCIATION SCREW THREADS (B.A.)

Number	Full Diameter Inches	Core Diameter Inches	Threads per Inch	Tapping Drill Size	Clearance Drill Size
0	·236	·189	25·5	No. 12	Letter B
1	·209	·166	28	,, 19	No. 3
2	·185	·147	32	,, 26	,, 12
3	·161	·127	34·5	,, 30	,, 19
4	·142	·111	38·5	,, 34	,, 27
5	·126	·098	43	,, 40	,, 30
6	·110	·085	48	,, 44	,, 34
7	·098	·076	53·5	,, 48	,, 39
8	·087	·066	60	,, 51	,, 43
9	·075	·056	66	1·5 mm.	,, 48
10	·067	·050	72·5	No. 55	,, 50
11	·059	·044	82·5	,, 59	,, 53
12	·051	·037	91·5	,, 62	,, 55
13	·047	·035	101·5	,, 65	—
14	·039	·028	110	,, 70	,, 60
15	·035	·025	120	,, 72	,, 64
16	·031	·022	135	,, 74	,, 67
17	·028	·019	150	,, 76	,, 69
18	·024	·017	170	,, 77	,, 72
19	·021	·014	180	,, 78	,, 74
20	·019	·013	211	,, 80	,, 76
21	·017	·011	231	—	,, 77
22	·015	·010	254	—	,, 78
23	·013	·009	282	—	,, 80
24	·011	·008	318	—	—
25	·010	·007	364	—	—

FUNDAMENTALS OF SHOPWORK

I

Classification of Tools

A. HAND TOOLS

Tools. Tools are necessary for the conversion of materials such as lumber and metal into useful articles. What they are, what they can be used for, and how to use them are of great importance to the worker. The great variety of tools may be divided by their use into definite groups. In each of these groups will be found the tools for major operations. Each tool has a special use.

Tools cost money; and they are made of metals — critical materials in peacetime and wartime. Every worker should learn how to take care of the tools he uses.

Care of tools. The care of tools consists of *storage, use,* and *conditioning.* The three classifications may be treated as individual subjects, but each also has an important bearing on the other. Improper storage affects the condition of the tool. The condition of the tool affects the successful and safe use of the tool. Satisfactory work cannot be done with tools in poor condition.

Storage of tools. Tools may be kept in a work bench, tool cabinet, or tool box; but regardless of where they are stored, each tool should have its own individual place so that it will be readily accessible. The racks or compartments should be so designed and placed that there will be no danger of one tool's coming in contact with another. If the racks or compartments are arranged so that tools can be replaced readily after they have been used, the bench top and working area can be kept clear and unobstructed. Idle tools on a bench top or on the floor are a hazard to anyone working there or passing by, and to one another. Keen-edged tools, such as chisels and knives, should be placed in their holders so that there will be no danger of cutting yourself or dulling the tool when picking it out or replacing it.

Use of tools. Tools should be used to do only what they are designed to do. You probably know that it is wrong to use a screwdriver as a chisel or a chisel as a screwdriver, but an untaught or careless person might thus misuse many tools. Such misuse is injurious both to the tools and to the person using them. You should learn what each tool is designed for and how it should be used.

Conditioning of tools. A tool in good condition is a tool at its maximum efficiency. Tools should be kept clean and free of rust. Rust is caused by moisture or dampness; its formation can be prevented or kept to a minimum by occasional wiping of the tools with an oily rag. When rust does form, it can be removed with a fine abrasive such as emery cloth or fine steel wool.

Lubrication of the moving parts of various tools is also a necessity, for all moving parts must be kept working freely. If such parts can be moved only with difficulty, lubrication is necessary.

A sharp tool seldom causes an accident. In most cases where a worker cuts himself, the tool is dull. The reason for this is simple: a tool in proper cutting condition will do its work without undue force or effort on the part of the worker. When exerting a great pressure to make a tool cut, the worker is thrown off balance, and a slip of the tool is more likely. Before using any tool, check to be sure it is in good condition. Never use a tool that is not in good condition.

1. LAYOUT TOOLS

The pencil and knife. Lines are made on wood with a *pencil* or a *knife.* Pencil lines are temporary lines and can be readily removed. Knife lines are cut into the wood and are therefore permanent; they are removed only with difficulty.

A pencil should be used for temporary layout lines. There are various types of pencils of varying degrees of hardness. Pencils that are used for laying out lines on wood should be fairly hard in order to hold a sharp point, but not so hard as to scratch deeply into the surface to produce a permanent line. The point of a pencil should be kept sharp at all times so that fine lines can be drawn. To draw long lines with a pencil, sharpen the pencil point to a wedge shape. The wedge-shaped point will not wear away so quickly, and a more uniform line will be produced. Dull pencils that produce exceptionally wide lines result in inaccuracy of layout. Lines of a permanent nature or where great accuracy of layout is required should be drawn with a knife. The sloyd knife shown in Figure 1–1 is designed for such work.

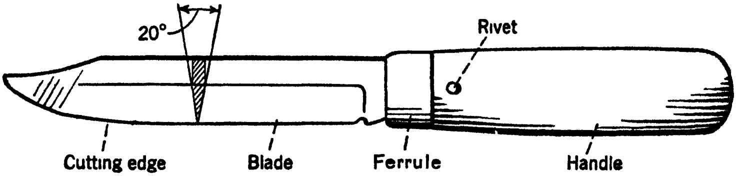


FIG. 1–1. The sloyd knife has a 20-degree taper from the cutting edge of the blade to the back edge of the blade.

Rules. A *rule* is a tool consisting of a straight-edged strip of metal, wood, or some other material, graduated in some units of measurement. Today there are but two universally accepted standards: the *English system*, based on the inch, and the ***French*** or *metric system*, based on the meter. All scales in common use are graduated or *calibrated* in either metric or English units; on some scales both metric and English units appear. (See Fig. 1–2.)

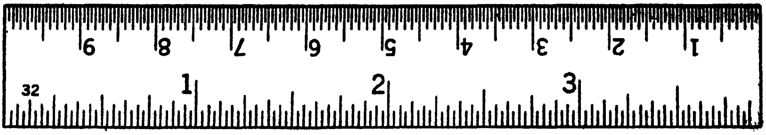


FIG. 1–2. A steel rule graduated in inches along one edge and in centimeters along the other.

The graduations on a rule calibrated by the English system are actual measurements of inches and fractions of inches. These fractions of an inch on a woodworker's rule are usually in 8ths or 16ths of an inch; that is, each inch is broken up into 8 or 16 equal parts. If the inch is divided into 8 parts, each part is equal to $\frac{1}{8}$ of an inch; if the inch is broken up into 16 parts, each part is equal to $\frac{1}{16}$ of an inch. For greater accuracy in measuring, there are rules with graduations in 32nds and 64ths of an inch.

Figure 1–2 shows a steel rule which is graduated in centimeters, millimeters, and half-millimeters on one edge, and in inches divided into 32nds on the other. In making a part whose dimensions are given in millimeters, use the metric side of the scale; and if the dimensions are given in inches and fractions of inches, use the inch side. Sometimes it is necessary to duplicate a part dimensioned in millimeters to the nearest inch measurements, or vice versa. In drawings, metric measurements are nearly always given in millimeters. To convert a metric measurement to inches, multiply the number of millimeters by .03937. For example, if a dimension on a drawing is given as 100 millimeters, multiply 100 by .03937 and get 3.937 inches. Using Table 1, Decimal Equivalents, in Appendix A, we would find that the nearest decimal to .937 is .921875. Since .921875 is the decimal equivalent to $\frac{59}{64}$, our measurement is $3\frac{59}{64}$ inches. This is not exact, but when working with a scale do not attempt to come closer than $\frac{1}{64}$th of an inch to a given measurement. When more accurate work is required, other measuring tools are used. When working with a metric scale from a drawing dimensioned in inches we should reverse the process.

There are many kinds of rules, but the function of each is basically the same — to measure distances. Certain types of rules may be used to draw straight lines or to test a surface in order to determine whether it is straight. *Folding rules*, *zigzag rules*, and *flexible-steel-tape rules*, ranging from 2 feet to 6 feet in length, are designed so that they may be closed to form a relatively small compact instrument which can be easily carried or stored. The folding and zigzag rules have their various sections held together by means of a swivel or folding joint made of metal. This permits the opening of the rule to its maximum length without loss of accuracy. The *caliper rule* is similar to the folding rule, but in addition it has a brass caliper slide graduated in fractions of an inch, usually 16ths and 32nds. The straightedge rule has a straight edge along its entire length. These rules are usually made from a single piece of material, 1 foot to 6 feet in length. When new, or if kept in good condition, they can be used for drawing straight lines and for testing a surface to see if it is straight or flat.

The trysquare. Most of the dimensions on drawings appear on lines drawn at right angles to each other. When work is laid out corresponding lines must be drawn or *scribed* (scratched). For locating these lines and for testing the trueness of the work as it progresses, the *square* is used. A commonly used type is the *trysquare.* (See Fig. 1–3.)

The trysquare is a layout tool consisting of a *blade,* calibrated in inches, and a *handle;* the blade and handle form an angle of exactly 90 degrees. The blade is set into the handle and is riveted securely in place. It must be treated with great care in use and carefully protected from damage when not in use. Before being replaced in its box after use, it should be wiped off with an oily cloth.

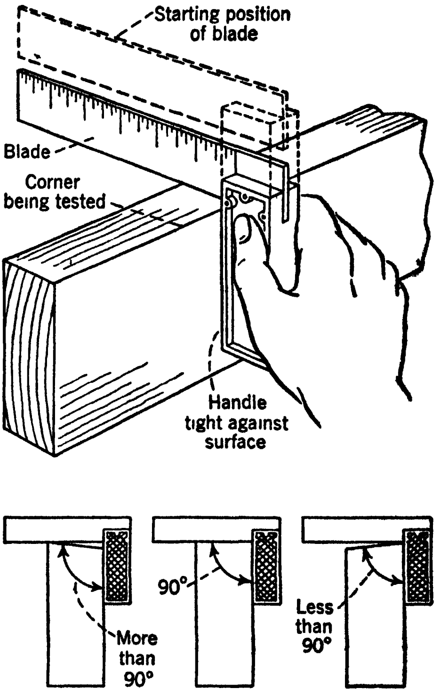


FIG. 1–3. Use of the trysquare.

As a testing tool, the trysquare is used to test the squareness of any corner; as a layout tool, it is used in drawing lines at right angles to an edge, face, or end of the work. When testing a corner for squareness — that is, to see if it is 90 degrees — the trysquare should be held by the handle, the handle placed tightly against one surface, and the blade brought down until it comes in contact with the adjacent side as shown in Figure 1–3. If the corner being tested is exactly 90 degrees, no light will be seen under the blade of the trysquare. If this corner is more or less than 90 degrees, light will be seen under the blade of the trysquare.

The framing square. The framing square is a tool used for laying out various angles. It can also be used in the same manner as the trysquare for testing the squareness of a corner. This square consists of two parts, the *tongue* and the *body* or *blade,* which form an angle of 90 degrees. The tongue is the shorter and narrower part, and the body is the wider and longer member. The tongue and blade are both marked in inches and fractions of an inch, so that the tool can be used to lay out any size of angle. The framing square will be considered in more detail in Unit IV.

✓ **The T-bevel.** The *T-bevel* is a tool that is used to lay out and test angles other than 90 degrees. It consists of a *handle,* a *movable blade,* and a *clamping screw.* (See Fig. 1–4.) The blade can be moved by loosening the clamping screw; when the blade is set, it is held securely by tightening the screw. The clamping device is designed so that the pressure of the fingers against the lever is sufficient to loosen or tighten the blade.

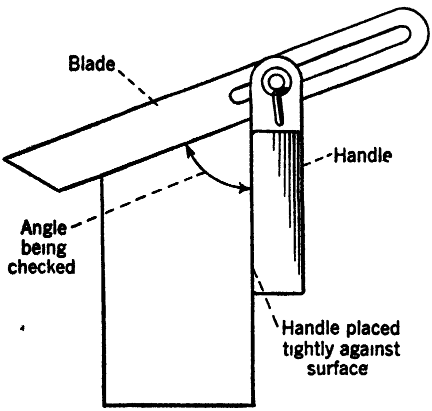


Fig. 1–4. Use of the T-bevel.

The bevel can be set at any angle with the aid of a protractor or a framing square, as shown in Figure 1–5. When the protractor is used for setting the bevel, the center reference mark on the protractor must coincide with the corner formed by the blade and the handle of the bevel. With the bevel in this position, the blade is then brought in line with the graduations on the outer edge of the protractor. Check back carefully on the center reference mark, because any movement will shift the blade at this point.

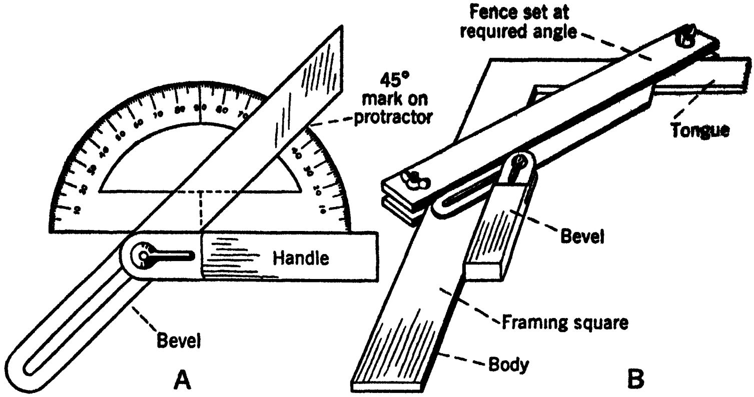


Fig. 1–5. Setting a T-bevel at a 45-degree angle with a protractor (*A*) and with a framing square (*B*).

A framing square equipped with a *fence* is used for setting the bevel. The fence is adjusted to the required angle by means of the graduations on the tongue and body; then the handle of the bevel is placed against the body and the blade adjusted so that it is flush against the fence. The clamping device which secures the blade in any set position should be tightened as soon as the blade is set. After tightening, the setting of the bevel must be checked by placing it on the protractor or against the fence and the body of the frame square.

The marking gage. The *marking gage* is a tool that is used for scribing lines parallel to the edge or the face of a piece of wood. Sometimes it is used to scribe lines across the grain or parallel to an end, but this practice is not advisable because the pin which does the marking will tear the wood fibers rather than cut them. The lines are scribed by a pin with a wedge-shaped point.

A marking gage consists of the *beam*, *head*, *thumbscrew*, *shoe*, *faceplate*, *pin*, and *stop screw*. The beam holds the pin and carries the head. The thumbscrew is used to apply pressure to the shoe, thereby securing the head at any point along the beam. The faceplate is a piece of metal set into the head to prevent excessive wear. The stop screw prevents the head from sliding off the beam.

The way the marking gage is held in the hand and how it is placed on the wood have an important bearing on the successful use of this tool. In Figure 1–6 the marking gage is held in the hand with the first finger in front of the head and the other three fingers in back of the head, around the beam. The thumb is placed as far out as possible on the side of the beam.

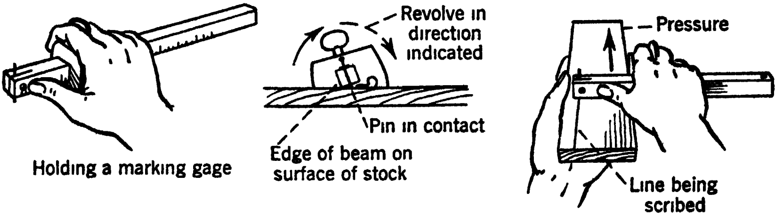

Holding a marking gage
Revolve in direction indicated
Pin in contact
Edge of beam on surface of stock
Pressure
Line being scribed

FIG. 1–6. Use of the marking gage.

The corner of the beam is placed on the surface of the wood with the head pressed firmly against the adjacent side. The gage is revolved with a slight twisting motion of the arm, while the head of the gage is kept pressed firmly against the edge as shown in Figure 1–6.

Marking gages with exceptionally long beams are known as *panel gages.* The *mortise gage,* another type of marking gage, differs from the other types only in that it has two pins on the same side of the beam; the inner one of which can be moved along the beam by means of a slide screw at the end. The purpose of the double pin is to scribe two parallel lines at the same time. The space between the movable pin and the head controls the distance from the edge of the stock that the lines are scribed. These two types of gages are shown in Figure 1–7.

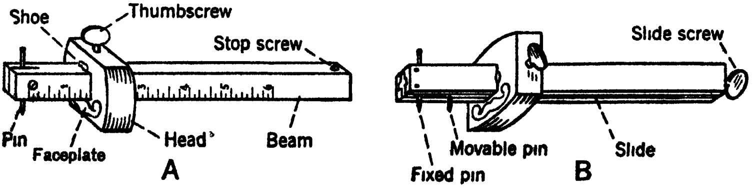


FIG. 1–7. A panel gage (*A*), and a mortise gage (*B*).

To scribe a line, the marking gage is set by moving the head along the beam until the space between the head and the point of the pin is equal to the distance that the line is to be scribed from the face or edge. This is done by holding the beam in one hand, then releasing the pressure on the shoe by turning the thumbscrew $\frac{1}{4}$ turn in a counterclockwise direction. With the rule in the other hand, the head is moved in either direction by means of the thumb of the hand holding the beam or by a pressure on the end of the rule that is in contact with the head, as shown in Figure 1–6. When the correct space between the point of the pin and the head of the gage has been established, the head is secured by turning the thumbscrew in a clockwise direction. After tightening the head in position, the setting should be rechecked with the rule. If the head has shifted, resulting in a slight error, it can be corrected by tapping the end of the beam on the bench. If the setting is undersized, the head can be moved down by tapping the stopscrew end of the beam; if it is oversized, it can be moved up toward the pin by tapping the pin end of the beam. This should be done without loosening the thumbscrew.

When setting a mortise gage to scribe two parallel lines, the thumbscrew should be loosened and the proper distance between the two pins set. (See Fig. 1–8.) This is done by turning the slide screw in either direction, thereby moving the inner piece toward or away from the fixed pin. After the setting between these two pins has been established, the head is set by moving the head in the required direction to obtain the correct distance between the movable pin and the head. This is done in the same

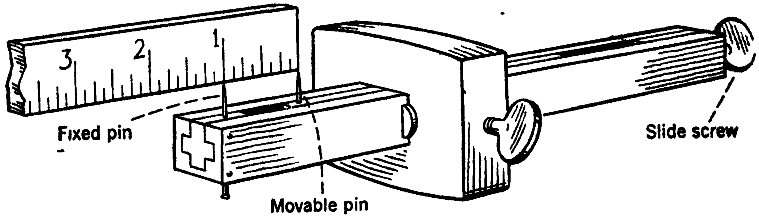


FIG. 1–8. Use of the mortise gage.

manner as described for the setting of the marking gage. The thumbscrew, which holds the head securely to the beam, also holds the movable pin in a fixed position by the pressure that is exerted on the beam, coming in contact with the slide to which the movable beam is attached.

Sometimes it is necessary to sharpen or reset the pin of a marking gage. The point of the pin should project no more than $\frac{1}{16}$ of an inch. The pin can be adjusted by first loosening the screw which clamps it in the beam, and then tapping the pin on the point to move it in, or on the opposite end to move it out. When the pin has been properly set, it is held securely by tightening the screw on the side of the beam.

The point of the pin can be sharpened with a small three-cornered file to produce a chisel point. The pin is sharpened by hand, working the file on opposite sides with the pin held securely in the beam. The sharp edge should be parallel to the head.

The divider, the trammel, and the compass. Sometimes it is necessary or convenient to lay off a given distance from some point, to repeat a given dimension a number of times, or to divide a line into parts. The tools used for this purpose are the divider, the compass, and the trammel.

The *divider* is a tool which scribes a line. It consists of two steel legs hinged at one end and sharpened to a point at the other end, a wing, a lock screw, an adjustment screw, and a spring. (See Fig. 1–9*A*.) The legs can be moved toward or away from one another by turning the lock screw in a counterclockwise direction, thereby releasing the pressure on the wing. Fine adjustments between the points of the divider can be made by means of the adjusting screw.

Some dividers are made so that hard, sharp points may be inserted as extensions of the legs. Sometimes in this type of divider only the points are made of steel, and the remainder is made of bronze, aluminum, or other suitable metal.

An improved form is the *lock-joint* type. By use of the lock nut the dividers can be locked at a given setting. This type of divider is useful when one dimension is to be laid off a number of

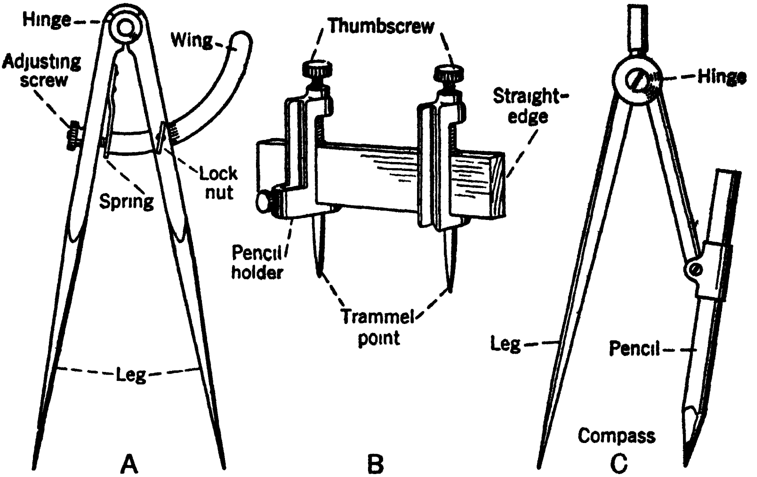


FIG 1-9. A divider (*A*), a trammel (*B*), and a compass (*C*).

times Because of this special usefulness it is sometimes called the *transfer divider*. Other types are the *spring divider* (sometimes called the *bow divider*) and the *split-nut divider*. They are basically the same as those described here.

The *trammel* is a tool used to scribe circles when the distances involved are too great for the use of the divider. A trammel consists of two metal points fastened to any straightedge by means of thumbscrews. (See Fig 1-9*B*) Most trammel points provide a means of holding a pencil so that the trammel may be used for drawing large circles

The *compass* also marks a line. (See Fig. 1-9*C*.) It consists of one steel leg with a sharp point and one leg with a holder for a pencil The compass differs from the divider in that the divider scribes or cuts the line into the surface, and the compass marks the line with a pencil. A compass line can be removed readily, but the divider line is relatively permanent.

The divider, the trammel, and the compass are set in the same manner. In order to set any of these tools the legs should be free to move; this is made possible by releasing whatever device is employed to lock them in position. The actual setting of the tool is done by measuring the required distance from the point of one leg to the point of the other as shown in Figure 1–10. When placing a divider, compass, or trammel on the rule in order to set the points, it should be kept in mind that the setting should be made with one leg at the 1-inch mark rather than at the beginning of the rule. The reason for this is that the point cannot be accurately located at the beginning of the rule. The loss of the 1 inch must be made up by adding the 1 inch to the setting being made; for example, if the divider is to be set for 4 inches, one leg will be at the 1-inch mark and the other leg will be at the 5-inch mark on the rule.

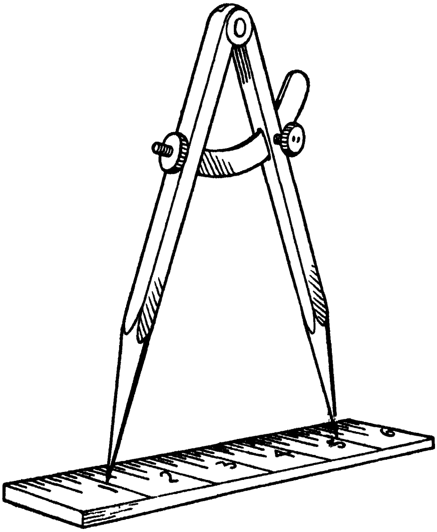


Fig. 1–10. Setting a divider. The trammel and compass are set in the same manner.

One of the uses of the divider, compass, or trammel is scribing or drawing circles. The setting of the dividers determines the size of the circle the tool will draw. The divider must be set for the *radius* of the circle that is to be drawn. The radius is half the diameter; a divider set for 4 inches will scribe a circle 8 inches in diameter. When drawing a circle, one leg is forced into the work, forming the center of the circle to be drawn. The divider or compass is revolved around this leg, and the outer leg marks the circle.

The only care required for the trammel, divider, or compass is keeping the steel points sharp. These may become dull or flattened after continued use or through misuse, making it necessary to sharpen the points again. This is done on a grindstone or a whetstone.

2. BORING TOOLS

The word *boring* means one thing to the woodworker and another to the machinist. To the woodworker, boring a hole means using an auger to make a hole in a piece of wood. To a machinist boring means enlarging and truing up a hole which has already been made.

Another word which conveys different meanings is the word *drill.* The woodworker calls the tool which penetrates the wood a *bit* or a *drill bit* and the device which holds and turns it a *drill* or *hand drill and brace.* The machinist calls the tool that penetrates the metal a *drill.* The tool that drives the drill may be a *breast drill*, a *hand drill*, a *drill press*, a *sensitive drill*, or an *electric drill*, but to a machinist the *driven* tool is always a *drill.* Drills will also be discussed in Unit V.

The hand drill. The hand drill is used to bore holes in wood. Its parts are shown and labeled in Figure 1–11.

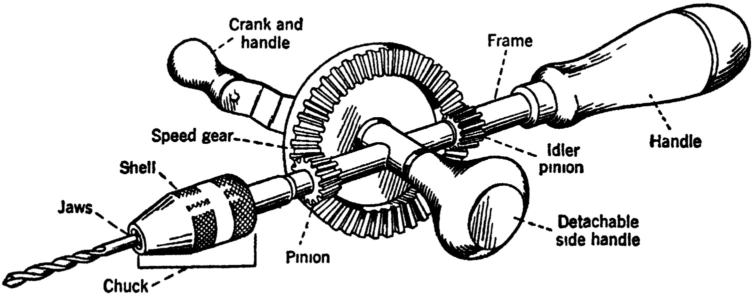


FIG. 1–11 Parts of the hand drill.

The hand drill is used with drills or bits having a round tang. The *tang* is the end of the bit by means of which it is held in the brace. The maximum chuck opening determines the size of a hand drill.

To open a chuck to receive a drill, the shell is held in one hand and the crank is turned in a counterclockwise direction. The jaws of the chuck should be opened only slightly more than is necessary to insert the drill. After the drill is placed in the chuck, the shell is held tightly in one hand while the crank is turned in a clockwise direction.

The hand drill is held by the handle with one hand, and the other hand is placed on the crank. The angle at which the drill is to enter the wood and make the hole is controlled by the hand which is holding the handle. This hand applies the downward pressure and must therefore be kept steady to prevent breaking the drill. The crank should be turned at a constant speed in a clockwise direction. When the hole has been drilled to the desired depth, the drill is removed from the hole by continuing the turning of the crank in a clockwise direction and drawing the drill out by the handle. Under no conditions should the rotation of the crank be reversed while drilling a hole. If that is done, the chuck may open and the drill come out. The material being drilled must be held securely in a vise or by some other means. If any attempt is made to drill holes in wood or metal which is not being held securely, the drill is likely to break.

The bit brace. The *bit brace* is a tool used, when boring a hole, to hold a bit or drill with a square tapered tang. Its parts are shown in Figure 1–12.

There are two types of bit braces, the *plain brace* and the *ratchet brace*. The ratchet permits the handle of a brace to be turned in the opposite direction without moving the bit. The ratchet collar controls the ratchet action.

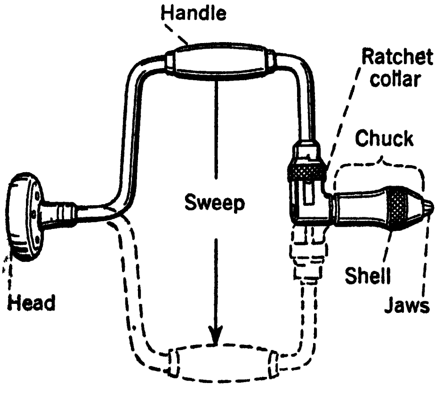


Fig. 1–12. Parts of the bit brace.

Bit braces come in various sizes, the most common of which are 6″, 8″, 10″, and 12″. The size of the brace is determined by the sweep — the diameter of the arc made by the handle as it is revolved. Braces having a small sweep should be used with small bits.

When placing a bit in the brace, the bit must be centered in the chuck and locked in place. The jaws of the chuck are opened by revolving the shell in a counterclockwise direction. They should be opened just far enough to set the corners of the tang in the V-grooves of the jaws. With the bit standing up in the jaws, the shell is turned so as to open the jaws more. As the jaws open, the bit will slide down. This is continued until the bit takes a sudden drop. The bit is now in place, and by reversing the rotation of the shell the jaws can be closed around the shank. A bit put into a chuck in this manner will be centered and cannot fall out.

The gimlet bit. The *gimlet bit* is used for boring small holes for screws and nails. Figure 1–13 shows a gimlet bit with its various parts labeled. The gimlet bit makes a hole by actually removing wood. The function of the point is to center the bit on the hole location and to start the cutting of the wood. The outer edge of the spiral is sharpened to do the cutting. The wood chips, as they are produced by the action of the cutting edge, collect in the flute and are carried up and out of the hole as the bit is revolved.

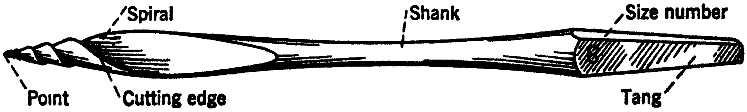


FIG. 1–13. The gimlet bit.

Gimlet bits are made in sizes ranging from $\frac{1}{16}''$ to $\frac{3}{8}''$, with gradations of $\frac{1}{32}''$. The size of the bit is measured across the widest part of the spiral. A number stamped on the tang indicates the size of the bit. A #4 bit will bore a hole $\frac{4}{32}''$ in diameter.

The twist bit. The *twist bit* is used to bore holes in wood for screws, nails, and bolts. (See Fig. 1–14.) The twist *bit* should not be confused with the twist *drill*, although they look similar.

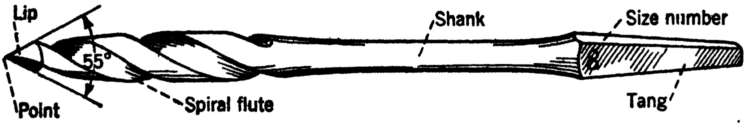


FIG. 1–14. Compare this twist bit with the gimlet bit, Figure 1–13.

The twist bit has a steeper cutting angle than a twist drill. The twist bit can be used for boring holes in wood only; but the twist drill can be used on both wood and metal. Figure 1–19, on page 21, shows a twist drill.

The twist bit is made of steel. Its cutting end is ground to a point; and a spiraled flute extends from the point upward along the shank. The end of the shank is a tang by which the bit is held in the brace.

Twist bits are made in sizes ranging from $\frac{1}{16}''$ to $\frac{5}{8}''$, with gradations of $\frac{1}{32}''$. The size of the bit is measured across the widest part of the bit and is indicated on the tang by means of a number. A #8 twist bit will bore a hole $\frac{8}{32}''$ in diameter.

The auger bit. The auger bit is more often used by the woodworker to bore holes than any other type of bit. It consists of four main parts: the *cutting end*, the *twist*, the *shank*, and the *tang*. (See Fig. 1–15.)

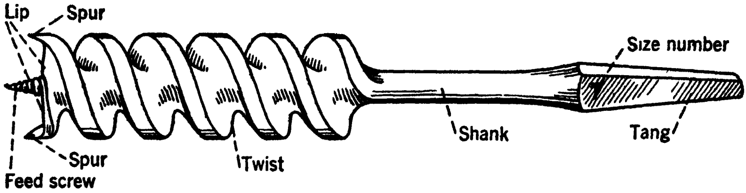


FIG. 1–15. Parts of the auger bit.

The cutting end consists of a feed screw, which draws the bit into the wood as it is turned; the spurs, which cut the fibers around the edge of the hole; and the lips, which follow the spurt and cut out the wood. The twist carries the chips, made by the cutting end, up out of the hole. (See Fig. 1–16.)

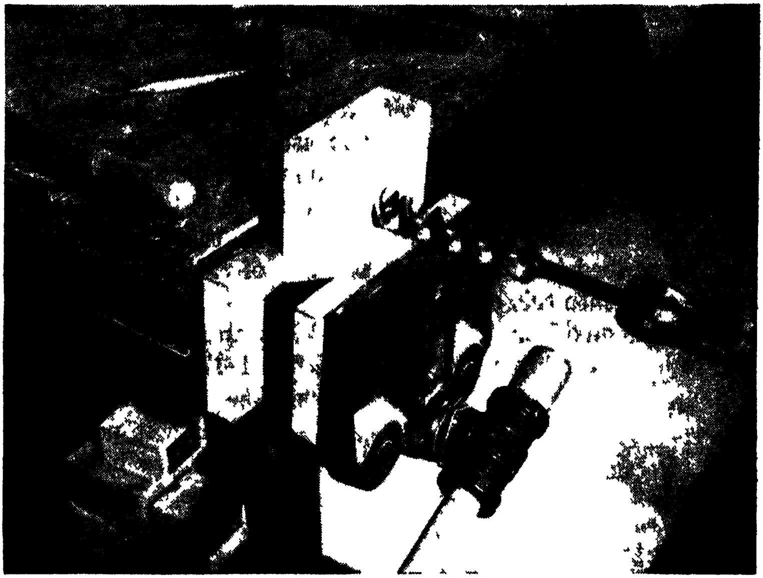


FIG. 1–16. Boring holes with an auger bit in stock held in a vise.

Auger bits range in sizes from $\frac{3}{16}''$ up, with gradations of $\frac{1}{16}''$. They are measured from spur to spur The bit size is stamped on the tang, the number indicating the width of the bit in sixteenths of an inch. A #7 bit will bore a hole $\frac{7}{16}''$ in diameter.

The Foerstner bit. The Foerstner bit is similar in action and use to the auger bit, differing in appearance only to the extent that there is no feed screw or centering point. It is used to bore holes in thin stock where there would be danger of splitting the wood with the feed screw if an auger bit were used. It is also used to bore holes part-way through, where if the auger bit were used the feed screw or spurs would go through the wood.

The Foerstner bit contains all the essential parts of an auger bit except the feed screw. The spurs are in the form of semicircular rims. The lips extend from the rim to the center. The slit in the side of the rim allows the wood chips to pass from the cutting edge of the bit up through the hole that is being bored.

On the smaller sizes of Foerstner bits the shank has a spiraled groove or twist to provide a means for removing the wood chips from the hole.

The sizes of the Foerstner bit range from $\frac{1}{4}$″ up, graduated in sixteenths of an inch. They are measured from spur to spur, with the bit size indicated by a number stamped on the tang. A #4 would indicate a bit that will bore a hole $\frac{4}{16}$″ in diameter.

In order to center a Foerstner bit, a circle the size of the hole must be scribed with dividers. The rim of the Foerstner bit is then pressed into this circle.

The expansive bit. The expansive bit is an auger bit which is used to bore holes from $\frac{7}{8}$″ to 3″. (See Fig. 1–17.) The bit comes supplied with two cutters which make it possible to bore any size hole within this range. The smaller cutter is used to bore holes from $\frac{7}{8}$″ to $1\frac{3}{4}$″, and the larger cutter is used to bore holes from $1\frac{3}{4}$″ to 3″. The various parts of the expansive bit are identical in name and function with those of the auger bit. The clamp and clamp screw are used to hold the adjustable cutters in place.

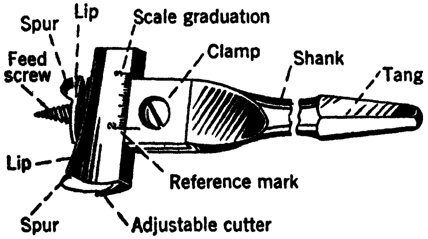


FIG. 1–17. The expansive bit.

The cutters of the expansive bit have marked along the lower edge graduations indicating the diameter of the hole that the bit will bore. On the clamp is a reference mark for setting the cutter. The clamp screw is loosened with a screwdriver, by turning the screw in a counterclockwise direction. When doing this, place the bit on the bench top rather than hold it in your hand. After the screw is loosened, thereby releasing the pressure of the clamp on the cutter, the cutter can be slid in either direction for setting. The graduations on the cutter indicating the diameter of the hole in inches and fractions of an inch must be brought in line with the reference mark on the clamp. The screw is tightened after the cutter has been set.

The countersink. The countersink is a bit used to taper screw holes so that the head of a flathead screw will set flush with the surface of the wood or slightly below the surface. The cutter is shaped at an angle equivalent to the slant or taper of the underside of a flat-head screw. (See Fig. 1-18.)

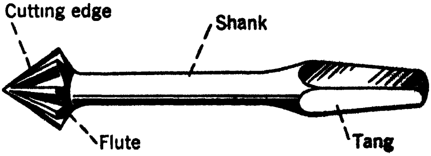


FIG 1-18. The countersink has a fluted cutting edge.

Countersinks come in sizes of $\frac{1}{2}''$, $\frac{5}{8}''$, and $\frac{3}{4}''$, the size indicating the greatest diameter of the cutter. The depth to which a screw hole should be countersunk will depend on the diameter of the screw head and the distance below the surface of the wood that the screw is to be set.

The twist drill. The twist drill is primarily a metalworking drill, but it can be used for wood. (See Fig. 1-19.) These drills come in a greater range of sizes than can be obtained in the regular woodworking bits and are extremely useful when boring small holes.

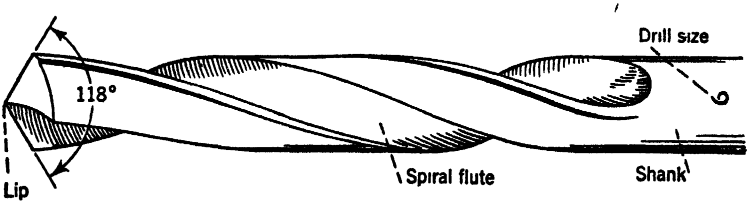


FIG. 1-19. Close-up of a twist drill.

Twist drills are marked for size by means of numbers, letters, or fractions. The numbers range from 1 to 80; #1 drill will bore a hole .2280″ in diameter (approximately $\frac{15}{64}''$) and #80 drill will bore a hole .0135″ in diameter (a little smaller than $\frac{1}{64}''$). The letter-marked drills run from *A* to *Z*; the *A* drill is .234″ in diameter ($\frac{15}{64}''$) and the *Z* drill is .413″ in diameter (a little less than $\frac{27}{64}''$). Twist drills marked in fractions of an inch range from $\frac{1}{64}''$ upward, in gradations of $\frac{1}{64}''$.

Metal-drilling bits. In Figure 1–20 two types of drills are shown; each has special advantages. For iron and steel the twist drill gives satisfactory service. The spiral flute causes the chips to rise to the top of the hole and so prevents choking. In drilling in soft metals, the twist drill has a tendency to screw itself into the material much as a wood screw does in wood. When a drill does this it is said to "hog in," and drill breakage is likely to result. To

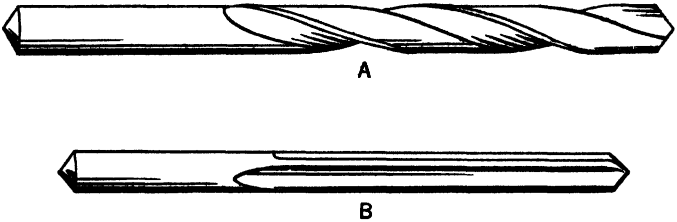


Fig. 1–20. A straight-shank twist drill (*A*) and a straight fluted drill (*B*).

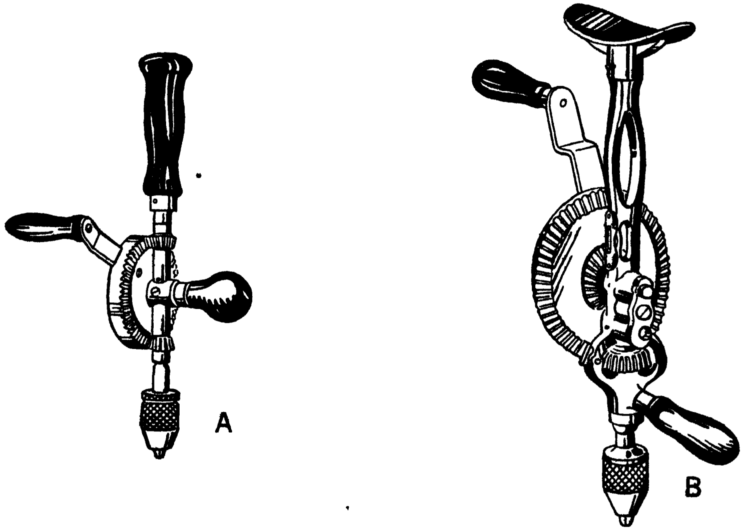


Fig. 1–21. A hand drill (*A*) and a breast drill (*B*).

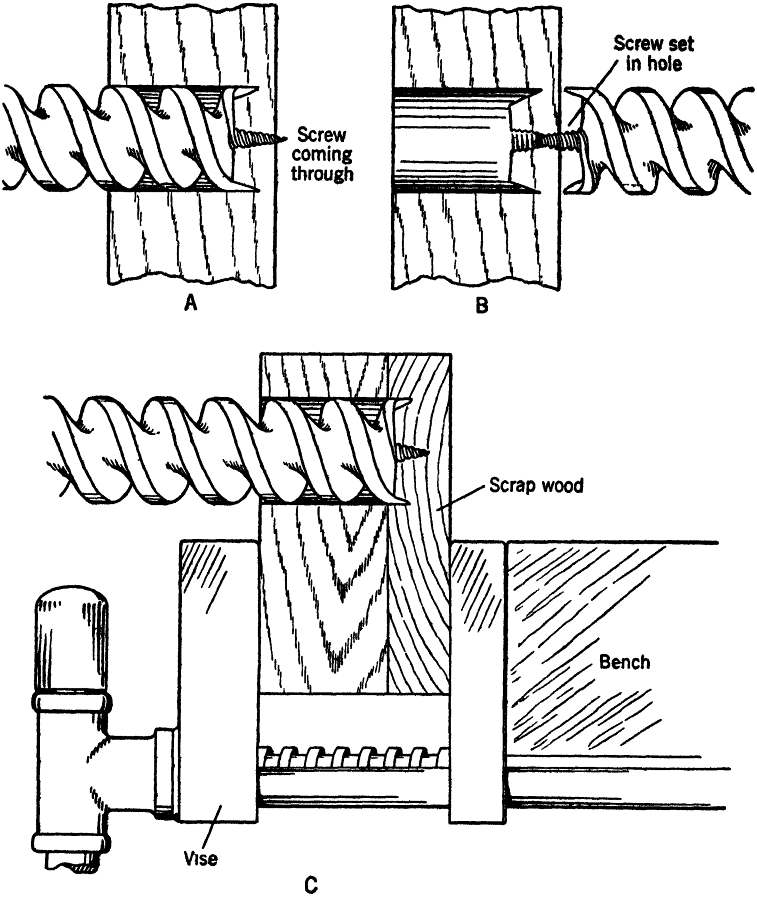


Fig. 1–22. In using a bit and brace, bore through the work only until the screw comes through (*A*); then complete the hole by boring from the other side (*B*). An alternative is to back up the work with a piece of scrap wood (*C*).

avoid this difficulty the straight flute drill is used in drilling the softer metals.

In Figure 1–21 two types of hand-driven drills are shown. The one to the left is held by the handle with one hand while the crank is turned with the other. Because of this manner of use it is called a hand drill. The drill to the right is called a breast drill. By leaning against the breastplate the operator exerts the force necessary for drilling.

Using a bit brace and bit. The stock into which a hole is to be bored must be held securely in a vise or held to the bench by means of a clamp. The brace is held with one hand on the head and the other hand on the handle. The hand that is placed on the head controls the angle at which the bit is to enter the wood; that hand must keep the brace steady. The handle of the brace is turned in a clockwise direction to bore the hole, and turned in the opposite direction to remove the bit from the wood.

When boring holes through a piece of wood with an auger bit or an expansive bit it is desirable to bore from both sides. If bored through from one side only, the stock should be backed up with a piece of scrap wood in order to prevent splitting the wood when the bit breaks through. (See Fig. 1–22.)

The brad awl. The brad awl is a tool resembling a small screwdriver. It is used to start holes which are to be made by an auger or expansive bit. It is also used to make small holes for screws and nails. (See Fig. 1–23.) The brad awl consists of a steel blade, tapered on opposite sides to produce a sharp edge, and set into a handle. The handle is equipped with a ferrule to prevent it from splitting. Brad awls come in sizes ranging from $\frac{5}{64}''$ to $\frac{1}{8}''$, the measurement indicating the width of the tip.

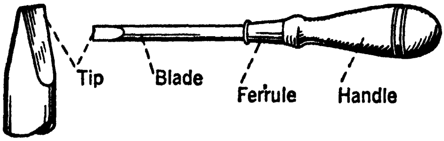


FIG. 1–23. A brad awl. At the left is a close-up of the tip.

When using a brad awl the tip should be placed at the intersection of the lines which locate the hole; the edge of the blade should extend across the grain. If the edge of the awl is run with the grain, the wood is likely to split. The brad awl should be held at right angles to the stock, and pressed downward into the wood. The tip is driven into the piece of wood and held there; then the brad awl is revolved one-quarter of a turn and taken out. When making deep holes for screws or nails, the brad awl is revolved several times while the downward pressure is maintained.

Sharpening bits and drills. Twist bits and twist drills are sharpened on a grindstone. There are three angles at the cutting end of the bit and drill that must be watched: the lip angle, the lip-clearance angle, and the clearance angle in back of the cutting lip. When grinding a twist drill or bit, the lip angle must be identical on each side and the length of the lips must be equal. Any difference in angle will result in only one lip's doing the cutting. If the lengths are not equal, the bit or drill will bore an oversize hole.

When grinding, hold the bit or drill against the face of the stone at the angle of the lip. Revolve it slightly until the lip angle has been ground, taking care not to grind away the lip.

Auger bits, Foerstner bits, and expansive bits, being similar in form, are all sharpened in the same manner. A special type of file, known as the *auger-bit file,* is used. This particular file is double-ended; one end has teeth cut on the faces of the file and the edges uncut, and at the other end the teeth are on the edges with the faces clear. A file of this type permits the sharpening of the spurs without damaging the lip. The spur of an auger bit must be sharpened on the inside only. The outside of the spur should never be touched with a file, for this would reduce the diameter of the cutting end of the bit and make it impossible to bore a hole. The lip is sharpened on the top to maintain the clearance of the cutting edge.

3. DRIVING TOOLS

The hammer. The carpenter's *claw hammer,* or *nail hammer* as it is often called, is used to drive or draw (remove) nails and brads. It has a steel head attached to a handle. The handle passes through the head and is held securely in place by means of wedges. The head includes: the *cheeks,* which are the sides; the *claws,* which are used to draw nails; the *face,* which is the part of the hammer used to drive nails; and the *neck.* (See Fig. 1–24.)

Nail hammers come in a variety of patterns and sizes, designed for various uses. The size of hammers is designated by a number such as 1, 1½, or 2; these numbers represent the weight of the hammer. #1 size weighs 20 ounces; #4 size weighs 5 ounces. Hammers of light weight should be used when driving small nails or brads, and larger nails should be driven with a heavier hammer.

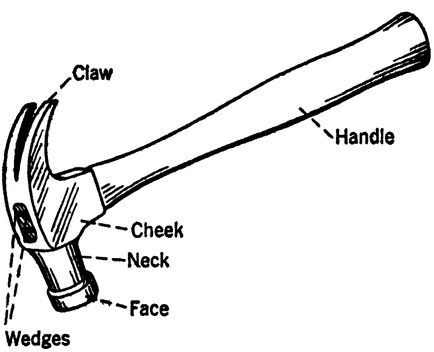


FIG. 1–24. Parts of the carpenter's claw hammer.

When using a hammer to drive nails, it should be grasped firmly near the end of the handle. The hammer blows are delivered by a wrist-and-elbow motion rather than by moving the entire arm at the shoulder. When it is necessary to strike very heavy blows, the full arm can be brought into use. The hammer must be held at such an angle that the face will strike the nail squarely. If each blow does not meet the head squarely, the nail will be bent.

When starting a nail, the nail is held in place by the free hand, and then given several light taps with the hammer. The hand that was holding the nail should be taken away before actually driving the nail. Make certain that the nail is well started into the wood before using a full hammer blow. A nail that has not had sufficient start will fly out of the wood when struck with a hard blow. Nails and brads should not be driven in flush with the surface of the board without the aid of a *nail set* (see page 30); otherwise hammer marks on the wood might result.

When pulling out nails, the claw is slipped under the head of the nail and the handle is pulled back to a vertical position. If this is not sufficient to remove the nail, a block of wood should be placed under the hammer head and the operation repeated. The block of wood will also protect the surface from which the nail is being drawn.

A hammer head should be held securely on the handle. If the head is loose the hammer should not be used, for then there is danger of the head's flying off. A hammer handle that is split is another source of danger, for a handle in such condition might break completely.

The face of the hammer should be clean and without nicks. Water, glue, oil, or grease on the face may result in the hammer's sliding off the work as a blow is struck. Rubbing the face of a hammer across a piece of sandpaper will remove glue.

The peen hammer. The *peen* hammer is widely used. The head is so shaped that one end, called the *peen*, can be used to produce dents or depressions or to set up tension in metal. When a hammer is so used, the process is called *peening*. Three types of peen hammers are shown in Figure 1–25.

The end of the head opposite to the peen is called the *face*. This face may be flat or slightly convex. The part through which the handle passes is called the *eye*.

The handle is made of straight-grained hardwood; hickory is excellent for the purpose. The weight, shape, and length of the handle in relation to the weight of the head all enter into what a mechanic calls the *feel* of a hammer. This feel is a combination of balance of the entire hammer and the spring of the handle. A hammer that is out of balance is tiring and hard to control.

Spring is given the handle by reducing the distance between the grip and the head. This spring distributes the effect of the blow. A handle that is too stiff jars the wrist of the user and has a tendency to break off where it enters the eye. The shape of the eye is important in the construction of the hammer head. It is made elliptical to keep the head from rotating about the axis of the handle.

In the cross-section insert of Figure 1–25, note that the eye is made smaller on the side through which the handle is inserted. This is done so that when the wedge is driven, the wood in the

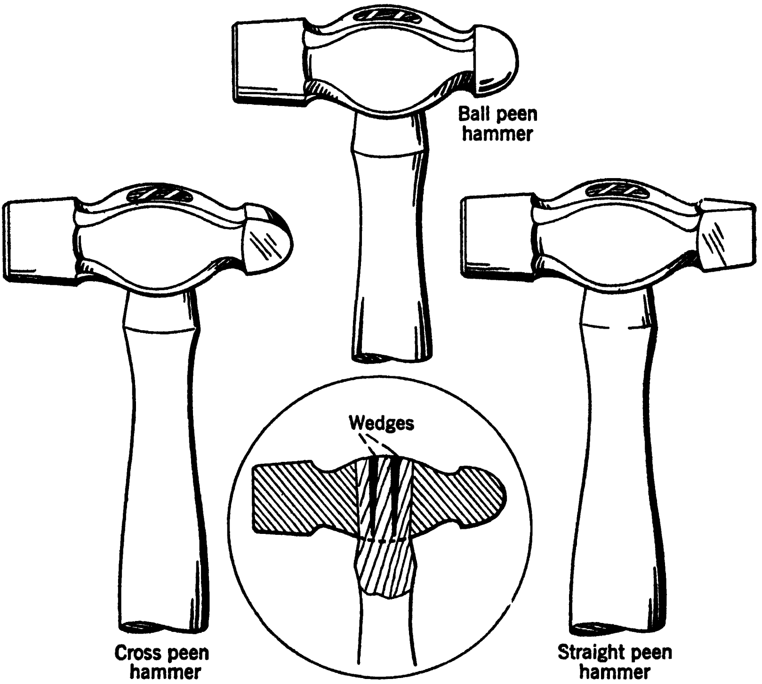


FIG. 1–25. Three types of peen hammers. The inset shows how a wedge keeps the head firmly on the handle.

eye can spread and so lock the handle in the head. This wedge is generally made of soft steel and must always be tight. A mechanic accustomed to using hammers always looks to see that it is tight before he strikes a blow. He has learned to do this because a loose head may fly off and cause serious injury. Like many other useful tools, the hammer can be the cause of serious accident if improperly used.

When working in close quarters the first step should be to make a slow-motion trial stroke with the hammer. This is done to make sure that when the eye of the user is concentrated on the work, the hammer will not be deflected by some unnoticed object in its path.

A hammer which shows cracks in either head or handle should be kept in a locked container until it has been repaired or it should be immediately dismantled and junked. Failure to observe these simple rules may result in broken wrists or fingers, head injuries, or loss of eyesight.

In describing the construction of the hammer, peening was mentioned. In peening, the surface struck is either dented by the blow or if so supported that it cannot dent, a tension is set up which causes it to stretch. A sag is taken out of a saw by resting the convex side of the sag on the anvil and peening the other side with a ball-peen hammer. The stretching of the surface on the concave side causes the two surfaces to become parallel.

Whenever a metal surface is struck with a hard-faced hammer, the surface is either stretched or dented or both. Sometimes a piece of metal must be driven or bent without marring its surface. Two methods can be employed to accomplish this. One is to place or hold a piece of soft metal over the surface to be struck so that it will receive the blow. The other method is to use a soft hammer. Hammers for driving pins are sometimes made of lead, copper, or an alloy such as Babbitt metal. Bending and forming hammers may be made of tightly rolled rawhide. There is a special type of mallet sometimes used for forming and bending. In this type, the body of the head may be made of wood or metal. The faces are made of material suitable to the purpose, such as rubber, fiber, soft metal, or plastic.

The mallet. The *mallet* is quite similar to the hammer. (See Fig. 1–26.) Being made of wood instead of metal, it is used for driving wood. When it is necessary to use a driving force on a chisel or gouge and the material to be struck is wood, the mallet should be used. If the material to be struck is metal, the hammer is generally used. The mallet is held and used in

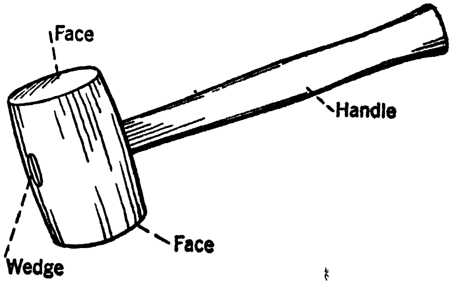


FIG. 1–26. Parts of the mallet.

the same manner as the hammer. The rules of safety are similar.

The nail set. A nail set is used in conjunction with the hammer to set nails and brads below the surface of the wood without marking or marring the wood with the face of the hammer. (See Fig. 1–27.) The sizes of nail sets range from $\frac{1}{32}''$ to $\frac{5}{32}''$; they indicate the diameter of the tip. Different sized nail sets should be used for different sized nails, but in any case the tip of the nail set should be smaller in diameter than the head of the nail it is used on.

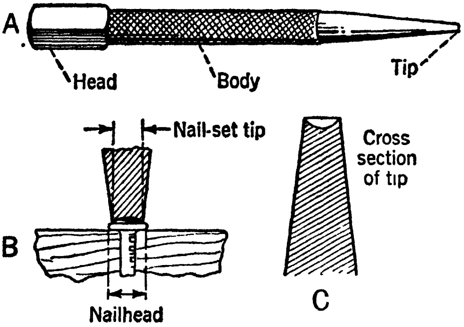


FIG. 1–27. Parts of the nail set (*A*), and its use (*B*). Close-up of the tip is shown in *C*.

The tip of a nail set is concave, as shown in the cross-sectional view. This produces a sharp rim that can dig into the head of the nail as the nail set is struck with the hammer, thus preventing the set from sliding off the head.

The nail set should be placed squarely on the head of the nail, with the body of the set at the same angle at which the nail was driven into the wood. The hammer should strike the head of the nail set squarely.

When a nail-set tip becomes flattened with use, the tool should be discarded, for it will no longer be capable of cutting into the head of a nail to prevent slipping. The head of a nail set should be kept square. From constant use, the head will burr over and become round. The rounded head is likely to cause the hammer to slip off when striking a nail set, and the burred edge may be chipped off from the hammer blows. The chips broken off under such conditions have a considerable force behind them and may penetrate the hand holding the nail set. The burr can be removed and the head made flat by grinding.

4. CUTTING TOOLS

The saw. The saw is a cutting tool having a tempered-steel blade with pointed teeth. Saws are manufactured to cut almost any kind of material. The teeth of saws vary in size and rake, depending on the use to which the saw is to be put. The *rake* is the angle at which the side of the tooth is cut, filed, or stamped in relation to a point line. The *bevel* is the angle at which the side of each tooth is filed. The *height* of the tooth is the distance between the point and the base, as shown in Figure 1-28. The height of the teeth is controlled by the number of points or teeth to the inch. A saw having 12 points to the inch will have shorter teeth than a saw having 8 points to the inch. The size of the teeth has a considerable bearing on the kind of cut a saw will make. Small teeth will produce a fairly clean and relatively smooth cut; a saw with such teeth should be used for fine cutting. Saws with large teeth are faster cutting but produce a surface which is relatively rough; these saws are used for rough work.

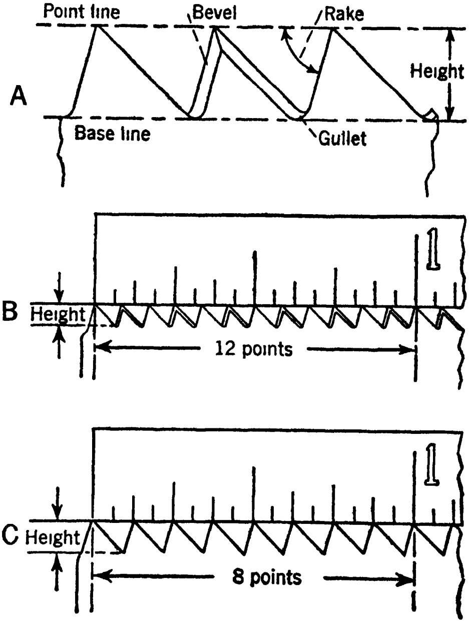


FIG. 1-28. Parts of saw teeth (*A*); and height of teeth with 12 points (*B*) and 8 points (*C*).

Set of a saw. With very few exceptions, every saw must have the teeth set. *Set* is a term applied to the alternate bending of the tip of each tooth from a straight line along the edge of the blade as shown in Figure 1–29. The purpose of set is to make the saw-cut slightly wider than the thickness of the blade. This is necessary to give clearance to the blade and prevent it from binding in the saw cut. If a saw has no set, the blade of the saw is in contact with the wood, with the result that the friction of the wood on the blade causes the blade to bind.

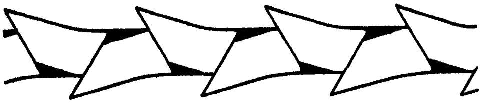


FIG. 1–29. Teeth of a saw, showing set.

There are two types of saws which are used for cutting wood, the crosscut saw and the ripsaw. The crosscut saw is used to cut *across* the grain of the wood; the ripsaw is used to cut *with* the grain. The shape of the teeth determines the type of saw as well as its use in relation to the grain of the wood.

The crosscut saw. The teeth of a crosscut saw have a shape different from those of a ripsaw, and they work differently. The angle of *rake* on a crosscut saw is 75 degrees, as shown in Figure 1–30*A*. The sides of each tooth are beveled or slanted to produce a sharp point at the top of each tooth.

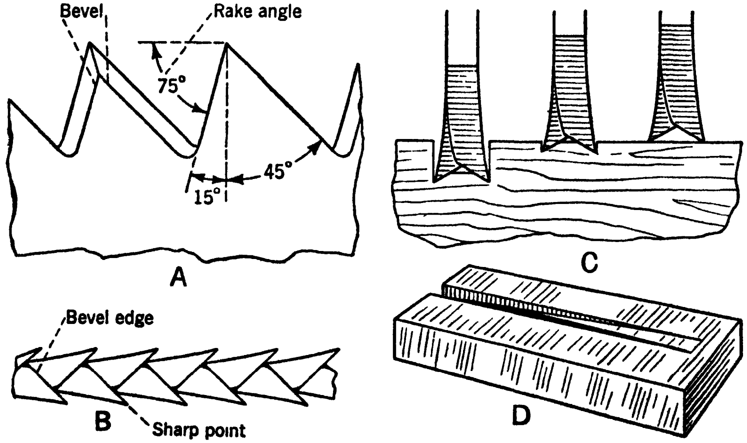


FIG. 1–30. The rake angle of a crosscut saw (*A*) and the cutting edge (*B*). *C* shows three steps in the cut of a crosscut saw, and *D* shows the cut made.

Saws do their work by removing a section of the material, called a *saw kerf.* The sharp points of a crosscut saw act very much like a series of knives, marking two parallel lines in the wood fibers instead of tearing them. These lines can be seen if a light stroke is made with a crosscut saw on a piece of wood. As the teeth are moved over the surface of the wood, the beveled tips of the teeth come in contact with the wood between the scored lines and chip out the material, producing the kerf. Figure 1–30*C* shows the successive steps which occur during this operation.

The ripsaw. While the ripsaw also does its work by removing some of the material to form the kerf, the shape of the teeth differs from that of the crosscut saw; for the ripsaw is used to cut *with* the grain, or parallel to the cells and fibers of the wood. Each tooth of a ripsaw has the rake angle filed at 90 degrees, as shown in Figure 1–31. The top of each tooth is a right angle, producing a tooth with a sharp edge rather than with a point like that of the crosscut saw. A comparison of Figures 1–30 and 1–31 will show these differences in the shape of the teeth of the crosscut saw and of the ripsaw. Ripsaw teeth are like a series of small chisels.

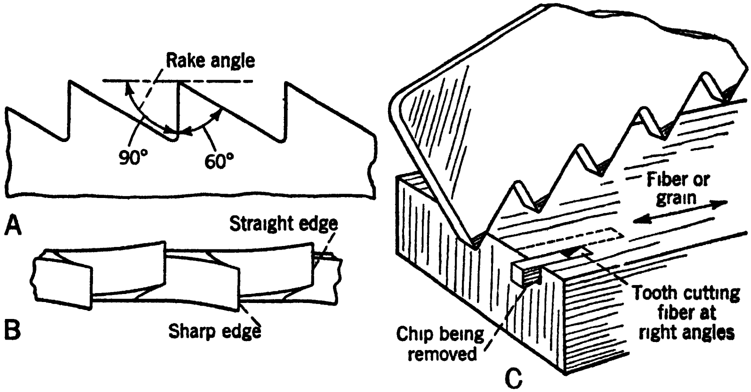


Fig. 1–31. The rake angle (*A*) and cutting edge (*B*) of a ripsaw. *C* shows how the ripsaw cuts.

The ripsaw tooth, being straight in front, strikes the wood at right angles to the fibers; it cuts the fibers at this point and chips out a section of the material, as shown in Figure 1-31*C*. Each successive tooth cuts its portion of the wood, and the chip so loosened is carried out of the kerf in the *gullet* of the tooth, which is the space between two teeth.

The handsaw. The saw most often used by the carpenter to cut timbers, planks, and boards is known as a *handsaw.* This has a steel blade, along the edge of which are filed teeth, and a handle at one end, as shown in Figure 1-32. These saws come in various lengths, ranging from 20″ to 26″. The number of points per inch also varies, ranging from 4½ to 11. Handsaws are made for either crosscutting or ripping.

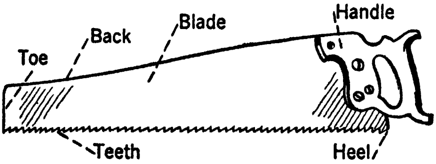


FIG. 1-32. Parts of the handsaw.

The backsaw. The backsaw is another form of crosscut saw used for fine cutting. These saws range in sizes from 8″ to 16″ long. They can be obtained with teeth varying in size. They range from 12 to 16 points per inch. The blade of the backsaw is relatively thin, requiring the use of a reinforcement to keep it rigid. The reinforcement consists of a strip of heavy steel clamped over the back of the blade; it is from this reinforcing strip that the backsaw gets its name. (See Fig. 1-33.)

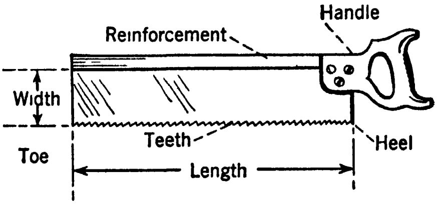


FIG. 1-33. The backsaw.

Unlike the handsaw, the backsaw should generally be held flat on the stock when it is used. A cut is started with a back stroke, drawing the blade toward you. The blade is guided by the thumb of the free hand. The handle should be raised slightly when the cut is started, and then gradually brought down to the surface of the wood as cutting progresses. (See Fig. 1-34.)

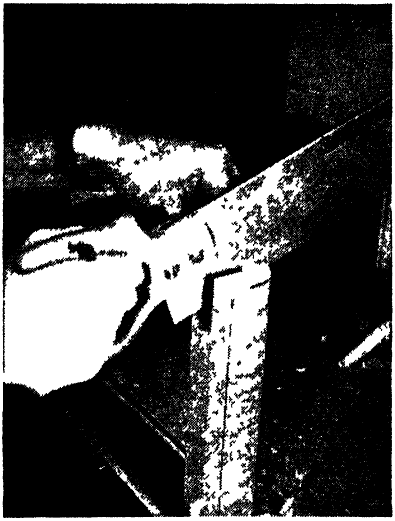


FIG. 1–34. The proper use of a backsaw.

When cutting small pieces of wood to length, a *bench hook* is generally used The bench hook is a board about 6″ × 10″ with cleats fastened to opposite faces near the ends. One cleat, on the underface, hooks over the edge of the bench; the other cleat, on the upperface at the opposite end, is used to brace the stock against. The stock to be cut is placed on the bench hook and held firmly against the cleat at the back. The cleat on the underside of the bench hook is in contact with the edge of the bench. The stock should be placed on the bench hook in such a manner that as the saw cuts through it will come in contact with the surface of the bench hook.

The compass saw. A compass saw is used to cut curves and circles in wood. It has a long blade, tapering to a point. Compass saws range in length from 10″ to 18″, and have 8 teeth to the inch The blade of the saw is relatively thick; therefore, a kerf cut with a compass saw is quite wide.

The keyhole saw. The keyhole saw has the same general appearance as the compass saw. Keyhole saws come in lengths ranging from 7″ to 14″, and have 10 points to the inch. They are used for fine work such as cutting small curves and cutting the slots of keyholes. When using the keyhole saw, the same instructions applying to the compass saw should be followed.

The coping saw. The coping saw is also used for cutting curves. It has a metal frame, a handle, and a removable blade. The blade is placed in the frame and held there by pins or loops which are part of the blade, or held in clamps which are part of the frame.

The better coping saws have frames equipped with blade-holding devices which can be revolved, making it possible to face the blade in any direction. The swivel at the upper end of the frame is free to move in any direction; the lower one, which has a threaded rod that screws into the handle, must be kept tight at all times.

The frame of a coping saw is longer than the blade that is fitted to it. This is necessary to keep tension on the saw blade. When placing a blade in the frame the handle is turned, thereby unscrewing the threaded rod of the lower swivel. The blade is fitted in the slots; and as the handle is turned, drawing in the threaded rod, the arms of the frame are drawn closer. The tension created thereby keeps the blade rigid. When inserting a blade in the frame, the teeth should point toward the handle so that the cutting is done on the pulling stroke rather than on the pushing stroke. Although the swivel-blade holders are designed to permit the blade to be turned in any direction in relation to the frame, the pins on these swivels should always be in the same direction. Failure to keep these in line will twist the blade, so the saw will not follow a line. So will a loose lower swivel.

The hacksaw.✓ The hacksaw is used by the metalworker. Its essential parts are the *frame*, the *handle*, and the *blade*. The frame should be rigid enough to hold the blade firmly in line without being too heavy. Figure 1–35 shows a hacksaw favored by many toolmakers and machinists. It is called the *solid-frame type*, which means that each saw is made for use with a blade of given length. This length may be 8″, 9″, 10″, or 12″. Blade tension is adjusted by turning the handle.

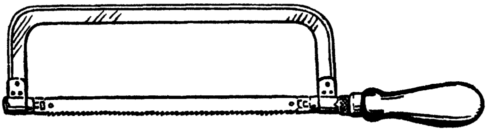


FIG. 1–35. A solid-frame hacksaw.

Some saws are made with adjustable frames. These frames, by simple adjustment, permit the use of several blade lengths.

Instead of the round handle shown in the illustration, handles resembling those on wood saws are sometimes used. These handles are less tiring to the wrist and are favored by mechanics who cut such materials as angle iron and tubing in their work. The solid-frame, round-handled type shown in the illustration is popular with benchworkers because it is light and responsive.

Blades may be *all-hard* or *flexible-back.* In the flexible-back blades, only the teeth are hard. In benchwork, using a light, rigid saw frame, the all-hard blades give excellent service. When working in awkward positions and when the work cannot be held rigidly, the flexible blade gives more satisfactory service. The number of teeth per inch is very important in the selection of a blade for a given job. Standard blades are made with 14, 18, 24, and 32 teeth per inch. The conditions governing the selection of both frames will be discussed under the use of the hacksaw, on pages 254–258. (See Fig. 1–36.)

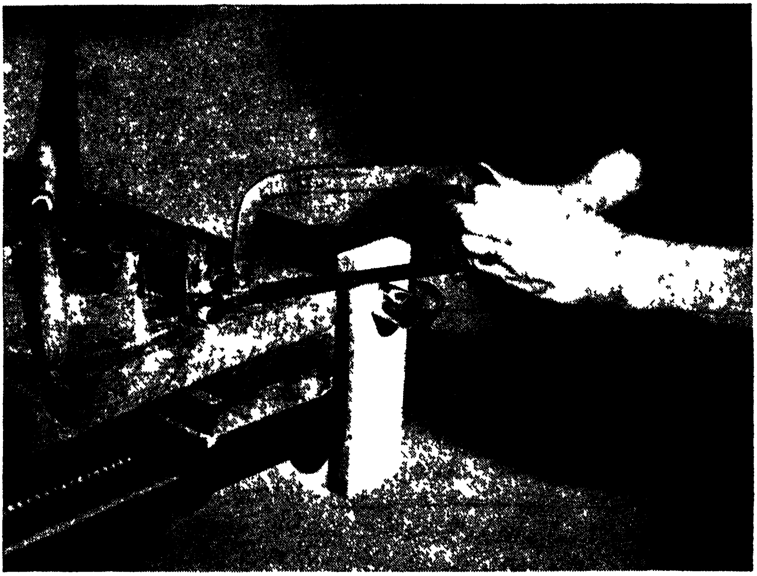


FIG. 1–36. Cutting a metal tube with a hacksaw. The tube is held in a block of wood to prevent crushing or marring the metal.

Conditioning a saw. In order to do its work, a saw must be kept in condition. The rake angle must be correct, the teeth must be set, and each tooth must be of like size and have its cutting edge at the proper angle. When it is necessary to recondition or sharpen a wood saw, each of these points must be checked carefully.

Jointing a saw. A saw will require jointing only when the teeth are uneven or incorrectly shaped. This operation consists of filing down the points of the teeth until they form a straight line, as shown in Figure 1–28. To do this, place the saw in a saw vise with the handle to the right. Place a mill file lengthwise on the teeth as shown in Figure 1–31, and pass it lightly back and forth until the top of each tooth touches the file. This operation will produce flat surfaces on the teeth that are too high, as shown in Figure 1–34. Keep the file flat, taking care not to tip the file from side to side during the operation.

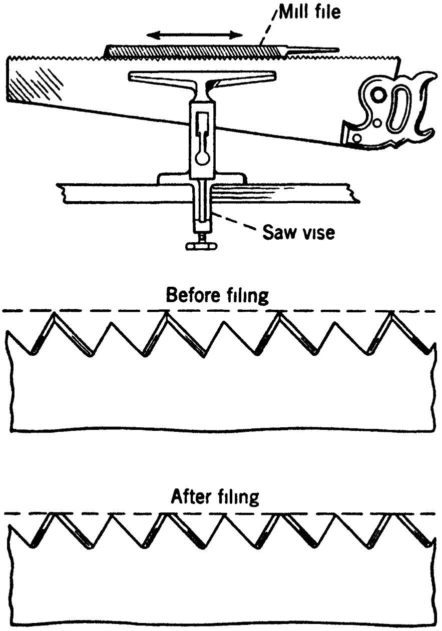


Fig 1–37. Jointing a saw.

Shaping the teeth of a saw. After completing the jointing operation, shape the teeth. The teeth must be uniform in size, and must have the correct angle of rake. Crosscut-saw teeth have a rake angle of 75 degrees, and ripsaw teeth have a rake angle of 90 degrees. When shaping the teeth, disregard the bevel as shown on the crosscut, and shape the teeth with the file held at right angles to the saw blade. The saw blade is placed in a saw vise, with the first section to be worked on coming within the jaws of the vise. The teeth should be from $\frac{1}{2}''$ to $\frac{3}{4}''$ above the vise.

Use a three-corner file to shape the teeth. Place the file well down in the gullet, at right angles to the blade, holding the file at the same angle as the rake of the tooth. Press the file against the tooth having the largest flat top, and start the filing. Continue until the center of the flat top made by jointing has been reached, as shown in Figure 1–38. Move the file to the next gullet and continue the filing operation until the other half of the flat top disappears.

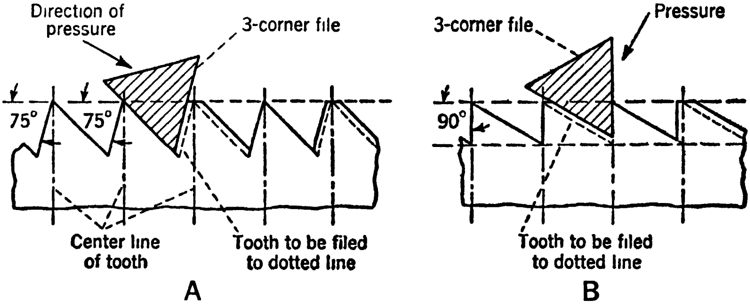


Fig. 1–38. Shaping the teeth of a crosscut saw (A) and of a ripsaw (B).

Setting a saw. When the teeth of a saw are correctly shaped, the next operation is setting. *Setting* a saw means the alternate bending or springing of the upper part of each tooth, one to the right and the next to the left, in order to make a saw kerf slightly wider than the thickness of the blade. (See Fig. 1–29.)

The depth of set should never exceed half the height of the tooth. Failure to keep this in mind may result in cracking the blade or breaking off the tooth. The general practice is to use a saw set like the one shown in Figure 1–39 for this operation. Such a set can be adjusted for teeth of various lengths and for different amounts of set.

The amount of set given to any saw depends on the kind of wood and the condition of the wood. Wet soft woods require the use of a saw with more set than dry hard woods require. For fine

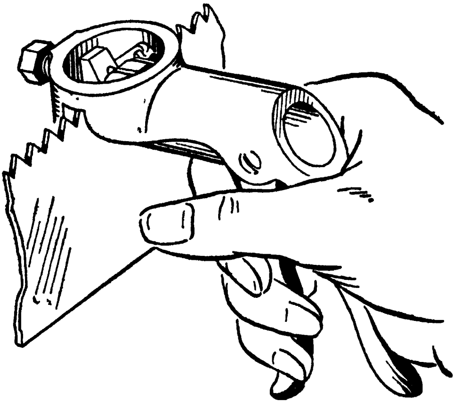


FIG. 1–39. Use of a saw set.

work on any dry wood, whether it be hard wood or soft wood, a fine-tooth saw with a minimum of set should be used.

Sharpening a saw. When the saw has been properly set, the final operation is sharpening the teeth. This operation involves beveling the teeth on the crosscut saw or making a sharp chisel edge on those of the ripsaw.

A slim, blunt saw file with parallel sides should be used; the size of the file depends on the size of the teeth to be filed. A crosscut saw with 5 or 5½ points to the inch requires a 7″ file; a crosscut saw with 6 to 9 points to the inch requires a 6″ file; and a crosscut saw with 10 or more points to the inch should be sharpened with a 5″ file. Ripsaws with 4½ to 6 points per inch should be sharpened with a 7″ file.

To file a crosscut saw, place it in the saw vise with the handle to the right. The bottom of the gullets should be no more than ⅛″ above the jaws of the vise. If more of the blade projects, the saw will chatter. Starting at the end of the blade, pick out the first tooth that is set toward you. Place the file in the gullet to the left of this tooth, and swing the file toward the left so that it crosses the blade at an angle of 45 degrees. (See Fig. 1–40.)

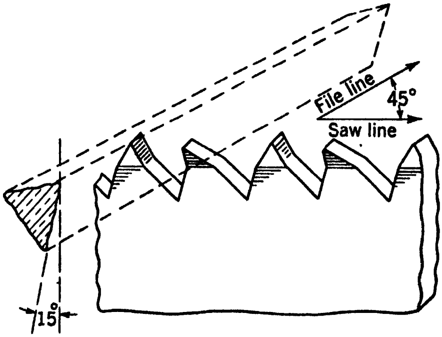


FIG. 1–40. The method of sharpening the teeth of a saw.

Hold the file level, with one hand on the handle and the other on the end of the file. Do not allow the file to rock during the filing operation. The pressure should be applied on the push stroke, and the file should be lifted slightly on the return stroke. Dragging the file back over the teeth on the return stroke will dull the file. This operation files the teeth to the left and right of the file at the same time. Continue the filing operation in the same gullet until the sides of the teeth in contact with the file are brought to a point. Remove the file from the first gullet, and skip the next gullet, placing the file in the third gullet. Filing is continued until the adjacent sides are brought to a point. Continue in this manner, skipping every other gullet, until the handle end of the saw is reached.

Now remove the saw from the vise and replace it so that the blade is to the right. Place the file in the gullet to the right of the first tooth that is set toward you, with the file swung around at an angle of 45 degrees across the blade. Work the file back and forth in the gullet between these teeth, maintaining the correct angle during the operation. Continue filing until the sides of these teeth are beveled to the point of the tooth. Continue placing the file in every second gullet, which is the gullet to the right of the tooth set toward you, until the saw handle is reached.

The filing of a ripsaw is identical to that of the crosscut saw, with one exception: When filing a ripsaw the file, instead of being swung around at an angle of 45 degrees, is placed in the gullet at right angles to the blade.

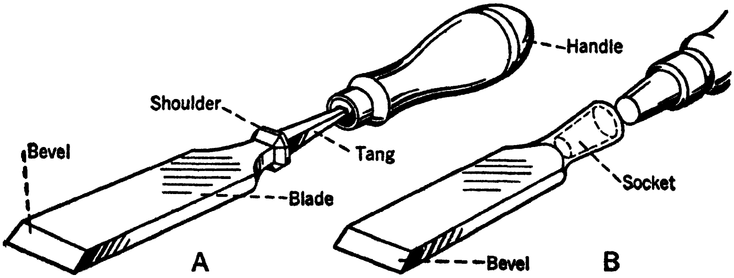


Fig. 1–41. A tang chisel (*A*), and a socket chisel (*B*).

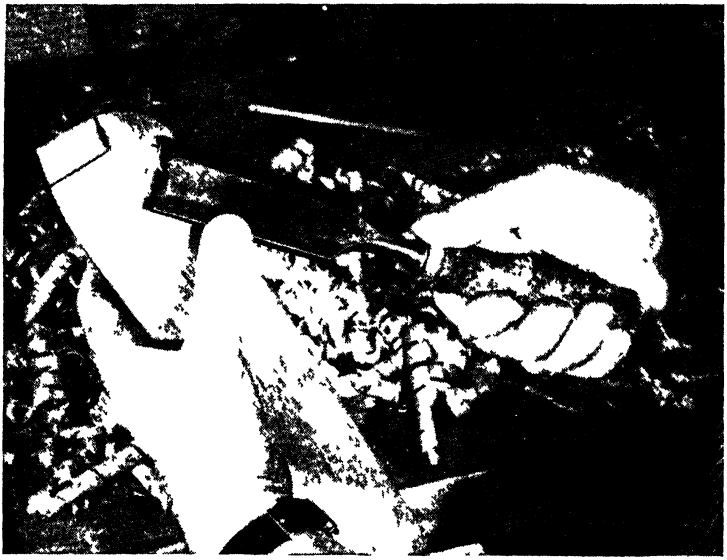


FIG. 1–42. Using a paring chisel to shape the end of a piece of wood.

The woodworker's chisel. The woodworker's chisel is a keen-edged cutting tool, used for cutting and removing part of a piece of wood. One of the most important woodworking tools, it is indispensable in the construction of wood joints. It is also used for shaping irregular surfaces.

Chisels are divided into two general classes, *tang chisels* and *socket chisels.* The tang chisel gets its name from the fact that there is a tang on the end of the blade which fits inside the handle. (See Fig. 1–41*A*.) The socket chisel has its handle fitted in a socket which is part of the blade. (See Fig. 1–41*B*.) The handle may be rounded at the end to fit the shape of a hand or it may have a flat end suitable for being hit with a mallet.

Chisels are also classified according to the work for which they are designed: *paring*, *firmer*, and *framing* chisels.

The *paring chisel* has a thin blade, with the cutting edge formed by a bevel ground at an angle of 15 degrees. It is used for light, fine work and should be used without the aid of a mallet or other heavy driving tool. (See Fig. 1–42.)

The *firmer chisel* has a heavier blade than a paring chisel, and its angle is 20 degrees. This chisel is used for both heavy and light work; and a mallet may be used to drive it.

The *framing chisel* has a thicker blade than the firmer chisel. Its bevel is ground at an angle of 25 degrees, and it is used for rough carpentry work.

Chisels are sized according to the width of the blade; they range in sizes from ⅛″ to 2″. A ½″ chisel has a blade or cutting edge ½″ wide.

Paring with a chisel. The grain of the wood must be taken into account when paring with a chisel. If paring is done against the grain, the chisel will have a tendency to follow the grain, digging into the wood and splitting it. If the direction of the grain is not definitely known, make a thin trial cut to see if the chisel digs into the grain. (See Fig. 1–43.)

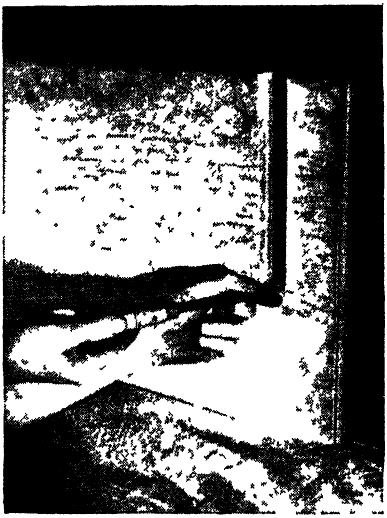


FIG. 1–43 Trimming the bottom of a dado with a paring chisel.

When paring, the chisel is placed on the surface, bevel side up, with the blade at a slight slant to the line of the wood. (See Fig. 1–44.) This position will produce a shearing or slicing cut. Place one hand on the blade of the chisel, pressing it against the sur-

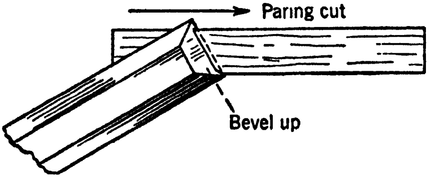


FIG. 1–44. Making a paring cut with a chisel. Notice that the chisel is held at an angle to its direction of movement — the length of the work.

face of the stock. This hand controls the forward movement of the chisel. The force that drives the chisel is exerted by the other hand, which is placed on the handle. The depth of cut taken by the chisel is controlled by raising or lowering the handle. Light cuts should be made with a paring chisel. If it is necessary to remove much wood, make a series of fine cuts.

When using a paring chisel on wide work to clean out grooves, place the bevel side down. (See Fig. 1-45.) Place the bevel flat against the surface, and control forward motion of the chisel with the hand on the blade. The force is exerted by the hand on the handle. Raising or lowering the handle controls the depth of the cut.

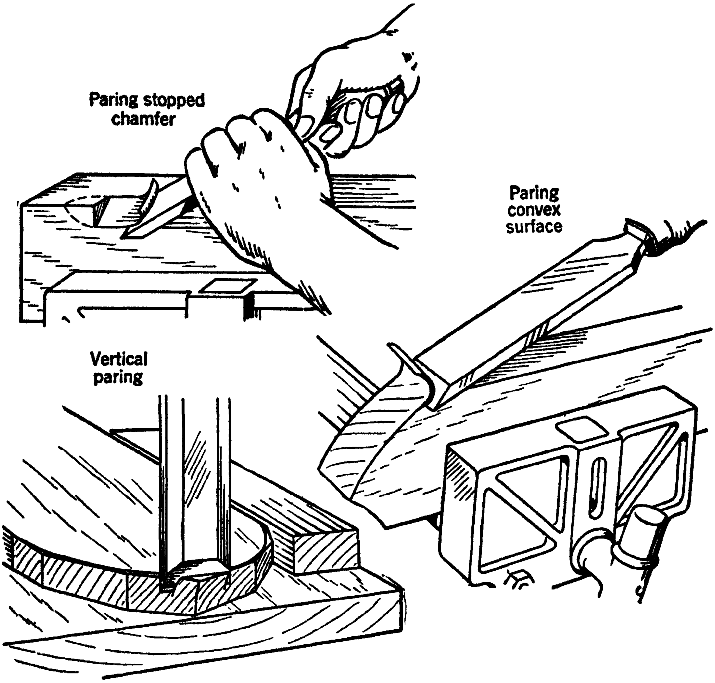


FIG. 1-45. Types of paring done with a chisel.

Deeper cuts can be made with a firmer or framing chisel, using the mallet for driving it. The direction of the grain of the wood in relation to the cutting edge of the chisel is an important factor. A chisel driven by a mallet has the same effect on a piece of wood as an ax. Used *with* the grain, the wood will split; but if the cutting edge of the blade strikes *across* the grain, the wood will be chipped or nicked.

To make a recess with a chisel, drive it with a mallet. Make a series of small cuts across the grain, holding the chisel at right angles to the surface. After making the vertical cuts, remove the chips by the paring method previously described, working with the bevel side of the chisel down.

The cold chisel. The metalworker may use a chisel for chipping, grooving, or for shearing. The *cold* or *flat chisel* is used for chipping and sometimes for shearing off metal. In shearing, the metal is first clamped in the vise. The chisel is then held so that its bevel rests on the jaw of the vise and its cutting edge touches the metal at an angle of about 45 degrees. When the chisel is struck, it acts like one scissor blade while the rear jaw of the vise takes the place of the other blade. Metal can be easily cut this way.

In chipping, the chisel is held similarly, but the bevel rests on the surface being cut, blows are sharper, and goggles are worn for protection against flying chips. Figure 1–46 shows the flat chisel and its two companions, the *diamond-point chisel* and the *cape chisel.* The V-chisel is not shown, but it is similar to the diamond-point except that its face, instead of being diamond shaped, is curved to form a *V*. It is used for grooving.

The diamond-point chisel is used to cut a V-shaped groove. It can be used to open a crack in a casting in preparation for welding. Sometimes, when a part is to be taken off a casting, instead of sawing it off it is grooved with a diamond-point chisel and then broken off with a hammer or sledge blow.

The cape chisel. The *cape chisel* is used for cutting rectangular grooves such as keyways. Its cutting edge is made wider than the stock immediately behind it to give clearance to the edge. Without this clearance it would bind in the groove as it cut.

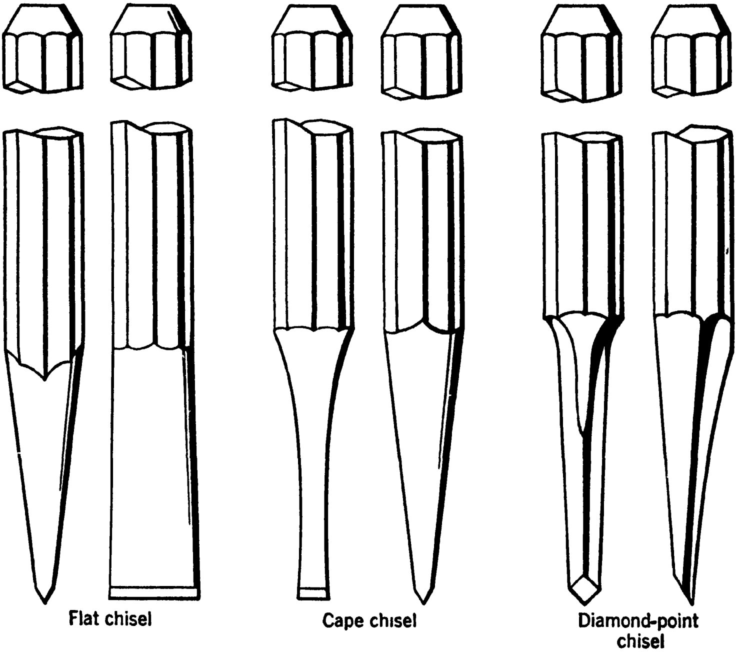


FIG. 1–46. A flat chisel, a diamond-point chisel, and a cape chisel.

Chisels can be made or dressed and ground to many different shapes to meet special conditions, but the same general principles are followed as those which apply to the three described.

The head of a well-made chisel is tapered off toward the face which receives the hammer blow. This is done to reduce the tendency of the head to spread, or *mushroom*, from repeated hammer blows. A chisel that has mushroomed should not be used.

Sharpening a chisel. The grinding and whetting of a chisel is done in the same manner as for the plane iron (see pages 67–68). Keep in mind that the angle of the bevel differs in some cases from those of the plane iron. The whetting angle of a chisel is 5 degrees more than that of the bevel angle.

Safety in using the chisel. The chisel is one of the most dangerous hand tools that the worker uses, and care must be taken to follow certain rules of safety. When using a chisel keep both hands on it and keep the fingers away from the cutting edge of the blade. Make certain that the material to be cut is held securely in the vise or held by means of a handscrew or C-clamp to the top of the bench. Never begin a chisel operation until the stock is secure. If it is necessary to remove a piece of stock from the vise or to remove a clamp that is holding the stock, put the chisel down on the bench. The only time a chisel should be held with one hand is when a mallet is used to drive it. When cutting with a chisel always cut away from yourself. If you carry a chisel around the shop, keep the cutting edge down so that no one walks into it. If these precautions are followed, there will be little danger of a person's being cut by a chisel.

The gouge. The gouge is a chisel with a curved cutting edge. Gouges are made in various sizes, ranging from $\frac{1}{8}''$ to $2''$ in width. There are two types of gouges, the *paring gouge* and the *firmer gouge.* (See Fig. 1–47.) The paring gouge has a bevel which produces the cutting edge, ground on the inside; the firmer gouge has the bevel on the outside. A paring gouge is commonly called an *inside-beveled gouge* and the firmer gouge is known as an *outside-beveled gouge.*

The gouge is used for making a rounded recess or a flute, or for shaping the curved edge of a piece of wood. A rounded recess or flute closed at the ends should be cut with a firmer gouge. The outside bevel will permit the gouge to scoop out the stock at the ends of the

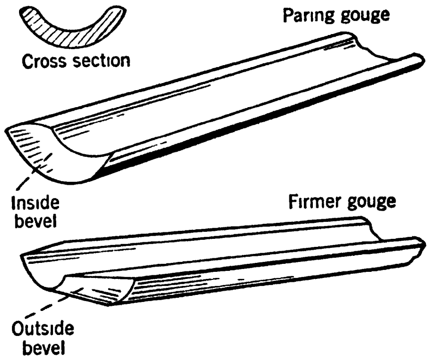


FIG. 1–47. The paring gouge has an inside bevel, and the firmer gouge an outside bevel.

flute. When making such a cut, form the ends of the flute or recess and remove the stock between these cuts. A concave groove, open at the ends, can be cut with a paring gouge, for the open end will not interfere with holding the gouge parallel to the cut. When cutting a curve on the edge of a piece of wood, the paring gouge should be used. (See Fig. 1–48.) The stock being cut should be placed on a cutting board to protect the bench as the gouge cuts through.

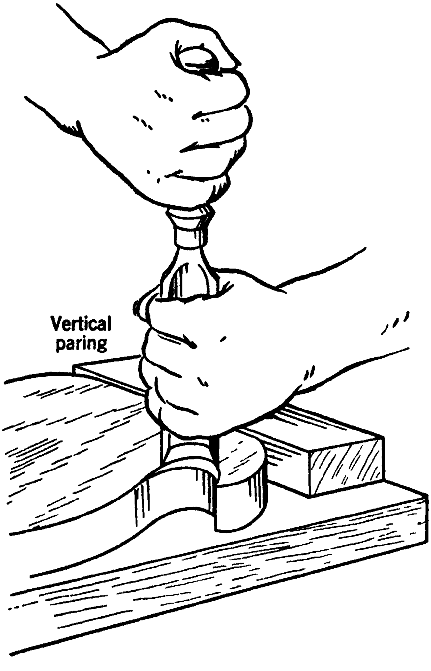


FIG. 1–48. The paring gouge is used to cut a curve on the edge of a piece of wood.

The gouge is a keen-edged cutting tool, and must therefore be handled with care to avoid accidents. When using the gouge, the stock to be cut should be held securely in the vise or to the bench by means of a clamp, leaving both hands free to manipulate the tool. The hands should be kept on the gouge while it is being used. Make all cuts away from you rather than toward you. If you follow these instructions you are not likely to cut yourself. (See Fig. 1–49.)

When holding the gouge, place one hand on the blade, keeping all your fingers behind the cutting edge. This hand controls the gouge. The pressure or force that drives the gouge is exerted by the other hand, which is placed on the handle. If a mallet is used to drive the gouge, hold the mallet in the hand that would otherwise be placed on the handle; at no other time should you remove the hand from the gouge while using it.

The direction of the grain must be taken into consideration when using a gouge. When cutting parallel to the grain, the cut must be made *with* the grain rather than *against* it. Failure to cut with the grain splits the wood. (See Fig. 1–50.)

To cut a recess with a gouge, make a series of shallow cuts. At no time should the full width of the gouge be used, for the corners of the cutting edge are likely to go below the surface of the cut and split the wood.

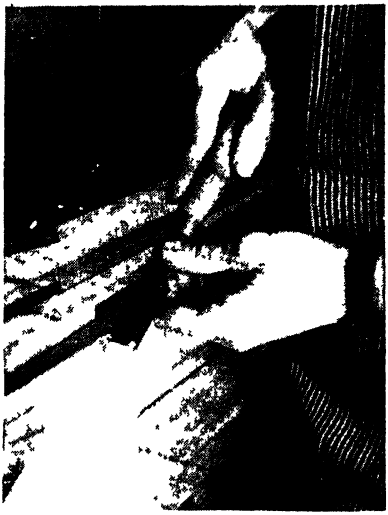


Fig. 1–49. Using a firmer gouge properly.

Sharpening the gouge. Sharpening a gouge consists of two operations: grinding the bevel and whetting the edge. Dull gouges do not necessarily require grinding to sharpen them; in fact, grinding should be done only when the cutting edge is nicked or when the bevel of the whetting angle is too great.

To grind an outside-beveled gouge use a grindstone, resting the gouge on the tool rest with the blade held at an angle to the face of the stone. Revolve the gouge, keeping the tool in contact with the tool rest and the face of the stone and maintaining the bevel angle at all times.

Inside-beveled gouges should be ground on a conical stone. The position of the gouge on the stone should be determined from the sweep or curve of the gouge. A gouge with a sharp sweep must be ground near the point of the stone, and one having a greater sweep should be ground farther in on the surface of the stone. When using a conical stone, the gouge is moved back and forth, taking care not to allow the forward motion to go beyond the point on the stone required for the ultimate sweep.

To whet a gouge, whether it has an inside or outside bevel, use an oilstone and a slipstone. The slipstone must have a rounded edge smaller than the sweep of the gouge. When whetting an outside beveled gouge, place it on the oilstone with the bevel resting on the face of the stone. This position must be maintained throughout the operation. As you pass the tool over the stone, give it a rolling motion. This step in the whetting operation will turn up a wire edge on the inside of the gouge. Next, remove the wire edge by placing the slipstone in the groove, keeping it flat against the blade. As you move the slipstone back and forth in the groove, give it a rolling motion so that the stone will touch every point on the cutting edge.

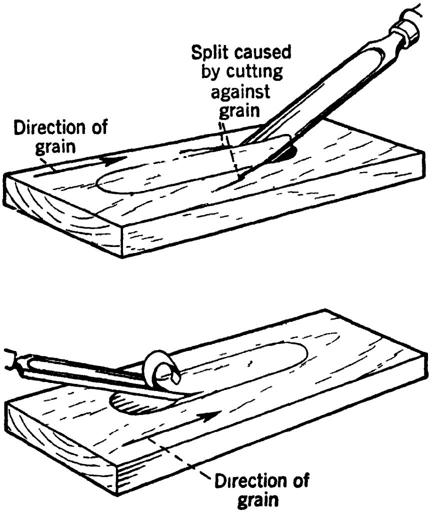


Fig. 1–50. Gouge cuts parallel to the grain should be made with the grain.

To whet an inside-beveled gouge use the slipstone, holding it parallel to the bevel to turn the wire edge out; then use the oilstone to remove the wire edge, keeping the blade flat against the face of the stone.

The sloyd knife. The *sloyd knife* is a layout tool involving the use of the point. The shank of the blade passes through the ferrule and into the handle where it is pinned in place with a rivet. In use, it should be held almost perpendicular to the surface on which the line is to be scribed, with the sharp edge facing in the direction in which the line is to be scribed. (See Fig. 1–51.) A straightedge or trysquare is used to guide the knife. It must be held securely against the stock, and the blade of the knife must be kept in contact with the straightedge or trysquare.

When scribing lines with the grain the knife will have a tendency to follow the grain, pulling away from the straightedge or pushing the straightedge away from the reference marks which locate the position of the line. This difficulty can be avoided by scribing the line lightly at first, and if necessary going over it a second time to deepen the cut. Keep your fingers away from the edge of the tool or the knife may slice off the tip of your fingers as it passes them.

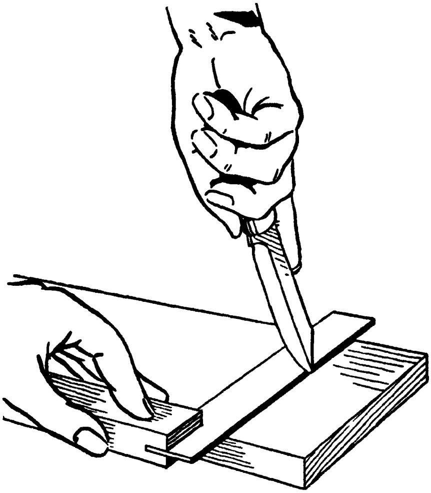


FIG. 1–51. Scribing a line with a sloyd knife and a trysquare.

A knife must be kept sharp if it is to do the work expected of it. Sharpening a knife consists of three operations: removing nicks, rebeveling, and honing. It is not always necessary to do all three. Nicks that are large enough to be visible must be removed on the grindstone. This is done by laying the blade flat on the tool rest, with the edge of the blade resting squarely against the stone. (See Fig. 1–52*A*.) The edge of the blade should be pressed lightly against the stone and then drawn slowly and evenly across the stone; repeat the operation until all nicks have been removed. This flattens the cutting edge, and must be followed by regrinding the bevel.

The rebeveling of the knife is done on the grindstone, as shown in Figure 1–52*B*. The grinding should be done on both sides of the blade. Place the knife on the stone with the bevel in contact with the face of the stone, holding it at the same angle throughout the entire grinding operation. Move the knife slowly across the face of the stone, from side to side, then turn it over and repeat the operation to grind the bevel on the other side. Care must be taken not to burn the tool. This can be prevented by using only a light pressure on the knife on the stone and by removing the knife from the stone and dipping it in water to cool the blade.

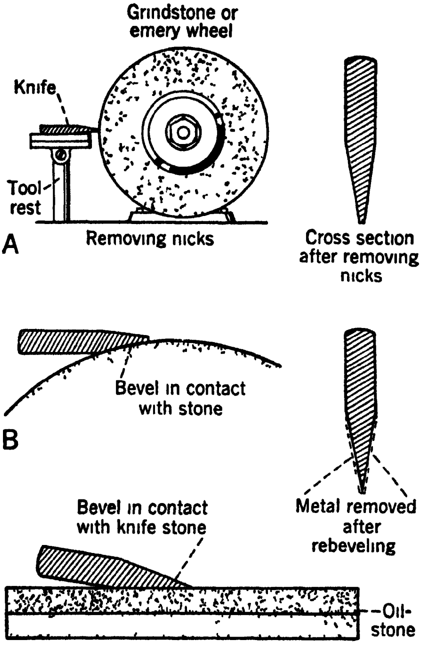

Grindstone or emery wheel
Knife
Tool rest
A
Removing nicks
Cross section after removing nicks
Bevel in contact with stone
B
Bevel in contact with knife stone
Metal removed after rebeveling
Oil-stone
C

FIG. 1–52. How to sharpen a knife

Honing should be done on an oilstone. If a knife is quite dull but does not need rebeveling, honing should be started on a coarse stone Place the knife on the stone with the bevel in contact with the stone, as shown in Figure 1–52*C* Apply pressure to the blade on the pushing stroke When the blade is turned over, apply pressure on the pulling stroke. Continue this operation on the coarse stone until a fine burr or wire edge appears. The wire edge is worked off on a fine oilstone

After rebeveling in which the wire edge appears, the use of a coarse oilstone can be dispensed with and the work of removing the wire edge can be done on the fine oilstone The procedure in this case is identical to that described in the previous paragraph.

The plane. A plane is a sharp-edged cutting tool used to dress a piece of stock to finished dimensions. Basically all planes are alike in that they have a sharp-edged metal blade held securely in some form of holder. Like saws, they are made in different sizes and forms to meet the requirements of various woodworking operations. The *bed* of a plane is a metal casting to which the knob, handle, and other working parts of a plane are attached. It includes the *toe* (front end), the *heel* (back end), the *mouth* (through which the cutting edge of the plane iron projects), and the *plane bottom*, or *sole*. The *knob* is the wood handle at the toe or front of the plane. The *handle* is made of wood and located at the back or heel of the plane. The *frog* is a metal casting attached to the bed of the plane by means of screws; it is used to hold the plane-iron assembly, lever cap, lateral adjusting lever, Y-lever, and adjusting nut. The *plane iron* is the blade of the plane; it has a cutting edge ground at one end. The *plane-iron cap*, along with the plane iron, forms the double plane iron. The purpose of the cap is to break the shavings as they are cut by the plane iron. The *cap screw* fastens the cap iron to the plane iron. The *lever cap* holds the double plane iron in position. The *cam*

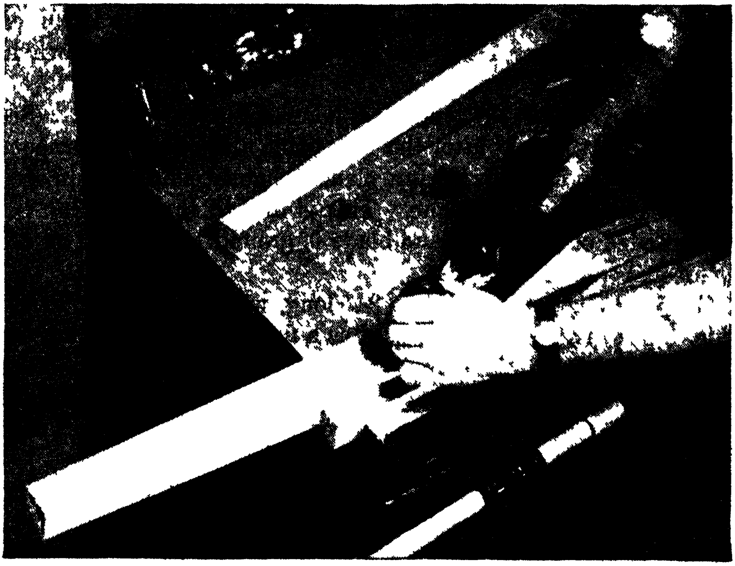


Fig. 1–53. Using a plane to dress a piece of wood.

applies the pressure between the lever cap and the plane iron. This pressure can be increased or decreased by turning the lever-cap screw under which the lever cap is placed. The *adjusting nut* and adjusting lever are the controls which vary the depth of cut of the plane iron. The *lateral adjusting lever* controls the movement of the plane iron from side to side. The smooth plane, jack plane, fore plane, and jointer plane are identical in appearance except for the length of the plane bottom and the manner in which the cutting edge of the blade is ground. (See Fig. 1–53.)

The *smooth plane* is made in various lengths ranging from $5\frac{1}{2}''$ to 10″, with blades ranging from $1\frac{1}{4}''$ to $2\frac{3}{8}''$ wide. (See Fig. 1–54.) As the name implies, the smooth plane is used to smooth the surface of a piece of wood and should be considered as a finishing tool. The blade of a smooth plane is ground straight across, as shown in Figure 1–55.

The *jack plane* comes in lengths ranging from $11\frac{1}{2}''$ to 15″, with blade widths of $1\frac{3}{4}''$ to $2\frac{3}{8}''$. It is a plane intended for heavy, rough work. The cutting edge of the jack-plane blade is curved as shown in Figure 1–55, and produces a surface as shown in the same figure.

The *fore plane* is 18″ long, and takes a blade $2\frac{3}{8}''$ wide. (See Fig. 1–48.) It is used after the jack plane and before the smooth plane. The cut made by the fore plane is slightly concave compared to the cut of the jack plane. This is due to the fact that the cutting edge of the fore-plane blade is ground to produce an arc $\frac{1}{32}''$ deep.

The *jointer* is a plane 22″ to 24″ long, with a blade $2\frac{3}{8}''$ to $2\frac{5}{8}''$ wide. (See Fig. 1–55.) It is used as a finishing plane, having the cutting edge of the blade ground straight. Its most common use is dressing and truing the edges of long stock that are to be glued or jointed together. Because of its extremely long bed, it is used to plane a long edge straight.

Adjusting a plane. There are four main adjustment points on a plane with which the woodworker must be familiar. (1) The *plane iron* and *plane iron cap* form a single unit which is called a *double plane iron.* The purpose of the cap is to break and roll the

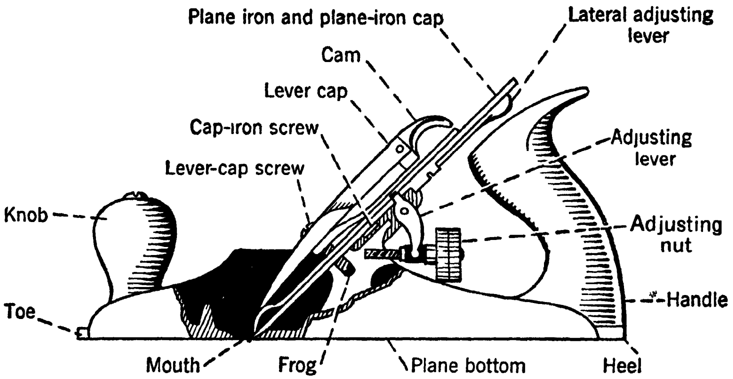


FIG. 1–54. Parts of the smooth plane.

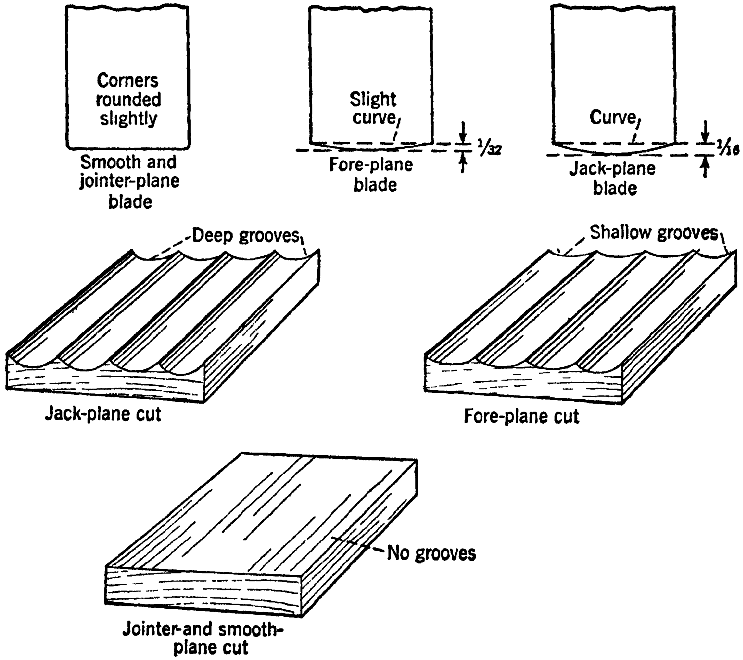


FIG. 1–55. Three types of blades and the cuts they make.

shaving as the plane iron cuts, thereby producing a smooth surface. If the cap is not correctly set in relation to the cutting edge of the blade, it will not function properly. This setting depends on the texture of the wood that is being planed. Under ordinary conditions the cap should be set $\frac{1}{16}''$ from the edge of the blade, as shown in Figure 1–56. When planing cross-grained or curly-grained wood, the cap should be moved closer to the cutting edge of the blade. How close this setting should be depends on the condition of the surface. If after being planed the surface shows signs of the plane's tearing the wood instead of cutting it, the cap should be moved closer to the cutting edge. When moving the cap, care must be taken not to allow the cap to come in contact with the cutting edge. When assembling the cap and plane iron, the cap is placed on the flat side of the plane, as shown in Figure 1–57*A*, with the screw in the slot and the cap at right angles to the iron. The cap is turned to bring it in line with the iron as shown in Figure 1–57*B*. It is then advanced toward the cutting edge, and moved up carefully and slowly until the correct space between the blade and the end of the cap is obtained. (See Fig. 1–57*C*.) The plane iron is turned over and placed on the bench top, and the screw which holds the cap to the plane iron is tightened with a screwdriver, as shown in Figure 1–57*D*. When taking the double plane iron apart to grind or sharpen the blade, the procedure is reversed, starting as in Figure 1–57*D* and working backward to 1–57*A*.

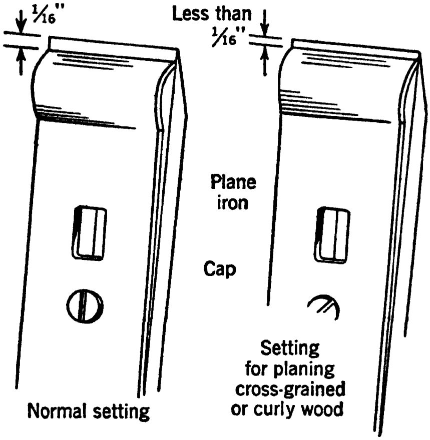


FIG. 1–56. Setting of the plane blade.

(2) The second adjustment controls the pressure applied to the *double iron* by the *lever cap*. After the double iron has been as-

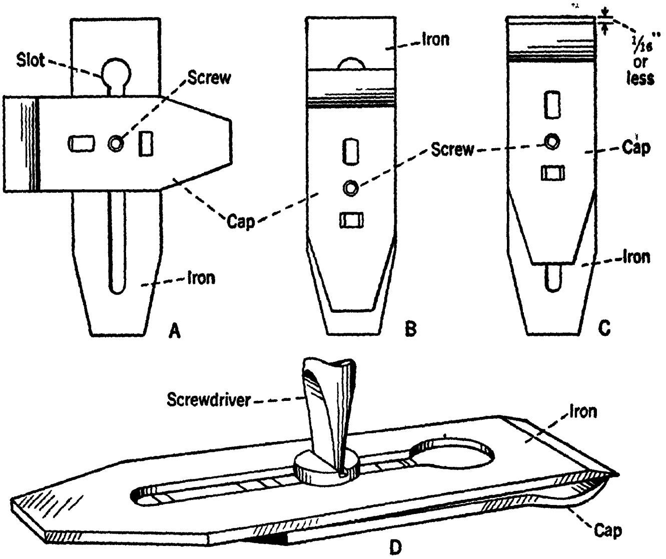


FIG. 1-57. Assembly of the double plane iron.

sembled, it is placed in the plane. Care must be taken that the cutting edge of the blade does not come in contact with the other metal parts. The projecting end of the *Y-lever* should set into the slot in the cap and the lateral adjusting lever should be in the slot of the plane iron. The lever cap is then placed over the lever screw, with the cam up. The lever cap is slipped under the lever screw and the cam pressed down to tighten the double plane iron in place. If, when the cam is pressed down, the double plane iron is not held securely, the cam should be released and the lever-cap screw given a quarter-turn in a clockwise direction. The cam can now be pushed down to apply the pressure. If the cam has to be forced down, the lever-cap screw should be turned in the opposite direction to reduce the pressure. When adjusting the lever-cap screw, no more than an eighth- to a quarter-turn should be made at any time.

(3) The third adjustment controls the depth of cut of the plane blade. This is done with the adjusting nut. As the nut is turned in a clockwise direction, the plane iron is moved in. A reverse motion of the nut will move the plane iron out. When setting a plane iron for depth of cut, hold the plane as shown in Figure 1-58. Hold it upside down in one hand, with the bottom of the plane in line with your eye. Place the other hand on the adjusting nut; as the nut is turned the blade moves in or out. To be set correctly for depth of cut, a projecting blade of a smooth plane and jointer should give the appearance of a hair line when seen along the bottom of the plane. Fore planes may have their blades projecting as much as $\frac{1}{32}''$; jack planes may have their blades projecting $\frac{1}{16}''$. One of the best methods of determining whether a plane is set for the proper depth of cut is to examine the shaving and the surface cut by a plane. The plane is set correctly if it cuts without undue force and produces a surface that is smooth. The shaving produced by a smooth plane or jointer should be tissue-paper thin.

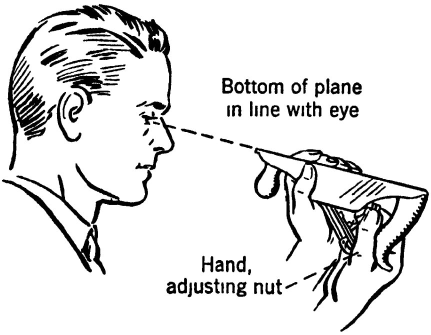

Bottom of plane in line with eye
Hand, adjusting nut

Fig. 1-58. Setting the plane iron.

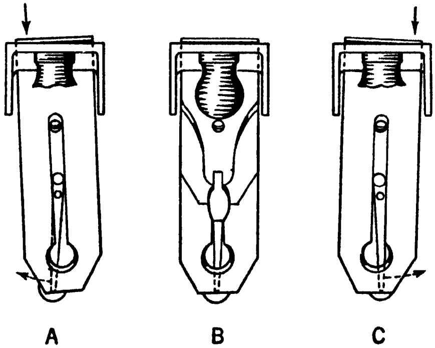


Fig. 1-59. Adjusting the plane blade.

(4) The fourth adjustment controls the lateral setting of the plane iron. To do its work properly a plane must have the blade

projecting evenly beyond the bottom. To make the adjustment, hold the plane as shown in Figure 1–59, with one hand on the lateral adjusting lever. As the lever is pushed to the left, the right-hand corner of the blade is pushed out, as shown in Figure 1–59*A*. When the lever is pushed to the right, the left-hand corner of the blade is moved out, as shown in Figure 1–59*C*. The correct setting should be as shown in Figure 1–59*B*, with both corners of the blade projecting an equal distance beyond the bottom of the plane.

Use of the plane. Stock that is to be planed should be held securely by a holding tool so that both hands are free to manipulate the plane. The surface to be planed should be in a horizontal position, if possible, and at the height of the hip. The knob of the plane is held in one hand and the handle of the plane in the other. Take a position directly back of the work, with your feet

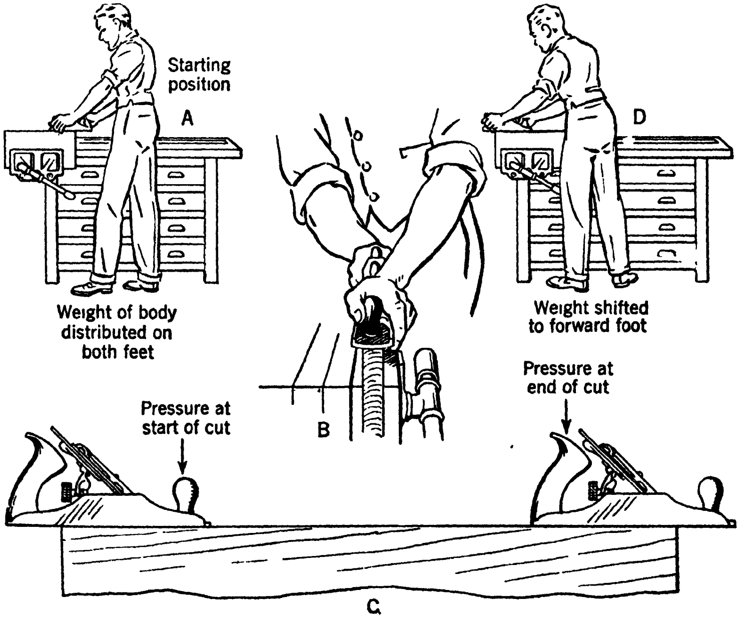

Starting position
A
D
Weight of body distributed on both feet
Weight shifted to forward foot
Pressure at end of cut
Pressure at start of cut
B
C

FIG. 1–60. Use of the plane.

spread slightly apart. (See Fig. 1–60*A*.) Hold the plane squarely to the face and parallel to the sides of the stock which is to be planed. (See Fig. 1–60*B*.) At the start of the cut, the pressure should be on the knob. As the end of the cut is reached, the downward pressure should be released from the knob and applied at the handle, as shown in Figure 1–60*C*. As the cut is made, the weight of the body is shifted from both feet to the forward foot. (See Fig. 1–60*D*.)

Three of the most common planing faults are making an edge *round*, *hollow*, and *out of square*. (See Fig. 1–61.) In most cases these are caused by not following directions. The rounded edge is the result of improperly applied pressure at the start and end of the cut: at the start the toe of the plane is allowed to tilt upward; and at the end of the cut, instead of being shifted from the knob to the handle, the downward pressure is kept on the knob.

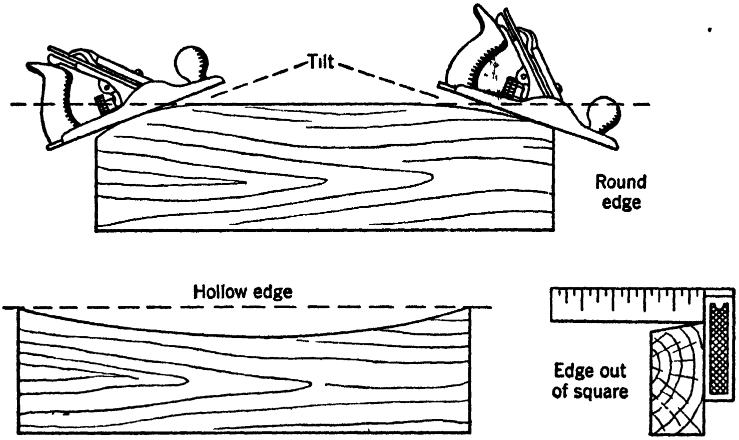


FIG. 1–61. Common planing faults.

A concave or hollow edge is usually the result of not keeping the plane parallel to the stock as shown in Figure 1–60*B*. It may also be caused by using a plane that is too short for the length of stock to be dressed. Long pieces should be dressed with a jointer rather than with a smooth plane. An edge that is not square can be the result of improper adjustment of the lateral lever or of tilting the plane from side to side.

The block plane. The block plane is a low-angle plane; that is, the blade is set so as to meet the wood at a lower angle than the smooth plane. (See Fig. 1–62.) It is made in lengths of 6″ and 7″, with a blade $1\frac{5}{8}$″ wide. The most important use of the block plane is to plane the end grain of the wood. It is used to plane the ends of small pieces of wood and to plane other small areas. The plane is held in one hand only, as shown in Figure 1–63. The instructions and precautions for the use of the smooth plane apply to the block plane also.

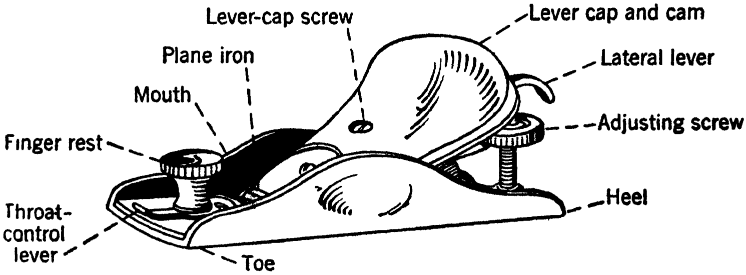


FIG. 1–62. Parts of the block plane.

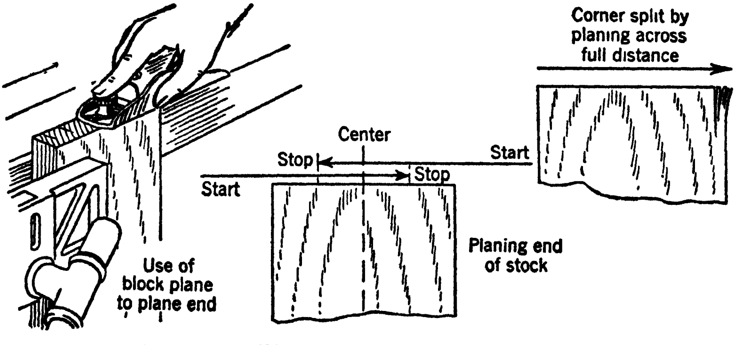

Corner split by planing across full distance
Center
Stop
Start
Stop
Start
Use of block plane to plane end
Planing end of stock

FIG. 1–63. Planing an end with a block plane.

The lateral lever, adjusting the screw which controls the depth of cut, and the lever-cap screw adjustments on the block plane are identical to those on the smooth plane. Some block planes have an adjustable throat lever. This controls the throat opening in the bed of the plane, making it possible to increase or decrease its size to meet varying wood conditions. The throat opening should be small when planing end grain It can be enlarged when planing edge grain or when taking relatively deep cuts Unlike the smooth plane, the block plane has a single iron; when placing the iron in the plane, the bevel of the blade should be up. (See Fig 1–64.)

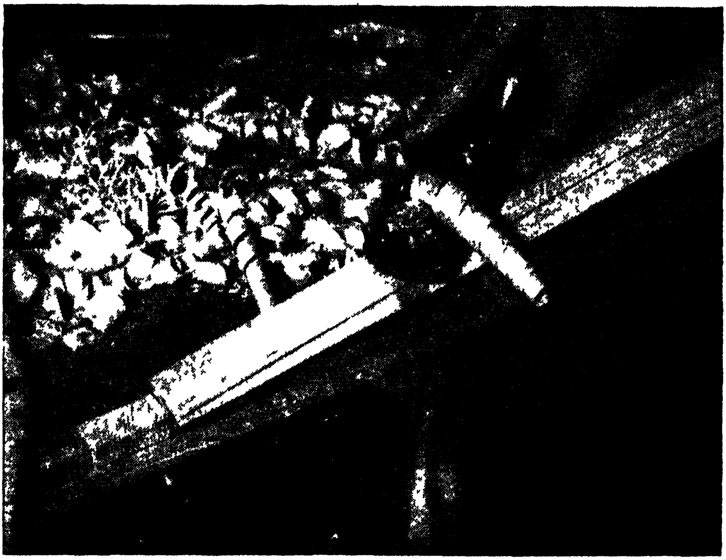


FIG. 1–64. Using a block plane to round a table leg.

When planing the end of a piece of wood with a block plane, the wood is held in the vise and the planing is done from one edge to a little beyond the center; then the work is reversed and the planing is done from the other edge to a little beyond the center. (See Fig. 1–63.) If the plane is worked across the end from edge to edge, the corner is likely to split.

The spoke shave. The *spoke shave* is a special form of plane with a bottom small enough to follow curves. (See Fig. 1–65.) The blade is adjusted both for depth and lateral position by means of the two adjusting nuts. The thumbscrew on the lever cap, as well as the lever screw, control the pressure of the lever cap on the blade. The blade of a spoke shave is placed in the frame with the bevel side down. The blade should project beyond the bottom of the frame no more than the thickness of a hair. When adjusting the blade you must sight along the bottom in the same manner as for adjusting the blade of a smooth plane. (See Figs. 1–66 and 1–67.)

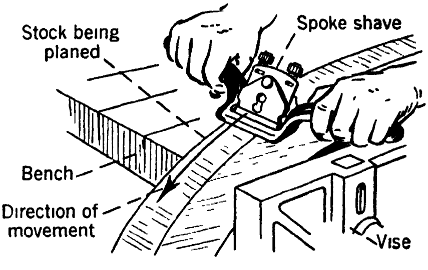


Fig. 1–65. Use of the spoke shave.

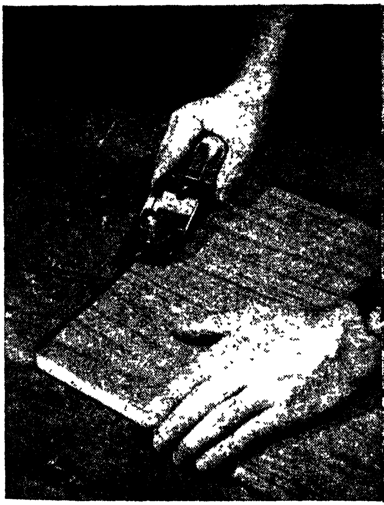


Fig. 1–66. Planing the edge of a veneer that has been glued to the end of a piece of stock.

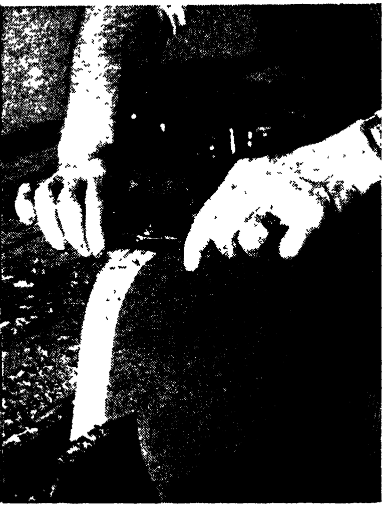


Fig. 1–67. Using the spoke shave to round a corner.

After the blade has been adjusted, it should be used on a piece of scrap wood to test for depth of cut. The spoke shave is held in both hands, as shown in Figure 1–65, and placed on the stock. As the spoke shave is pushed forward to make the cut, it will be necessary to twist the wrists to keep the blade in contact with the wood. Care must be taken to cut with the grain of the wood.

The combination plane. The *combination plane* is a special type of plane used to cut grooves and moldings. It is designed to take blades of various shapes and sizes. The blade can be varied for depth of cut by releasing the cutter bolt and turning the cutter adjusting wheel. There is no lateral adjustment on this type of plane. The plane is equipped with a *fence* to guide the cutter along an established edge. The depth to which a cut is to be made is controlled by the depth gage. In use, the fence of the combination plane must be kept in close contact with the surface of the wood.

The router. The *router* is a type of plane which is used to finish the surface of any recess requiring a smooth surface. It consists of a frame or bottom to which are attached knobs by which the tool is held. A cutter is held to the frame by means of a collar. An adjusting screw controls the depth of the blade below the bottom. In use, the blade should be set to cut no more than $\frac{1}{16}''$ at a time. When finishing a surface with the router, the depth of cut should be considerably less.

The scraper. The *cabinet scraper* is a tool used for the final smoothing before sanding. It consists of a frame, a blade, a clamp, and an adjusting screw. The blade is adjusted by loosening the two clamp screws, then setting the scraper on a flat board and pressing the blade lightly against the wood. While pressure is being applied with one hand, the clamp screws are tightened with the other, thereby holding the blade in the same position in the frame. The blade is bowed or sprung outward to allow the center portion of the blade to project slightly more than the ends of the blade by tightening the adjusting screw. The scraper is then tried, and if necessary the adjustment is changed to produce a thin, even shaving.

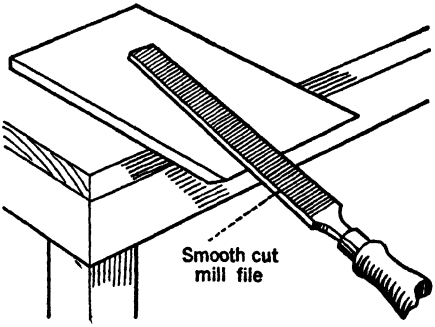


FIG. 1–68. When a cabinet-scraper blade needs sharpening, the old burr is removed with a smooth-cut mill file.

A cabinet-scraper blade has its cutting edge ground or filed at an angle of 45 degrees. The cutting edge is turned over with a burnisher to produce a burr. When a blade requires sharpening, the old burr must be removed and a new one formed. To remove the old burr a smooth-cut mill file is used. (See Fig. 1–68.) The bevel is ground to the correct angle of 45 degrees on a grindstone or with a mill file. The wire edge produced by either of these operations is removed on the oilstone, following the same procedure as outlined for whetting a plane blade except that in this case the bevel angle of 45 degrees must be maintained. The blade is now ready to draw and turn the burr, using a *burnisher*. (See Fig. 1–69.) *Drawing* is the operation of stretching the metal to produce a fine wire edge. The edge is drawn with a few firm strokes of the burnisher, held flat on the face side.

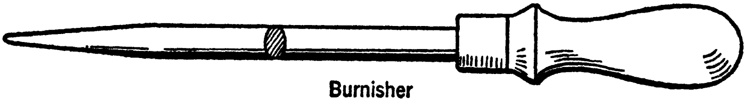


FIG. 1–69. The burnisher.

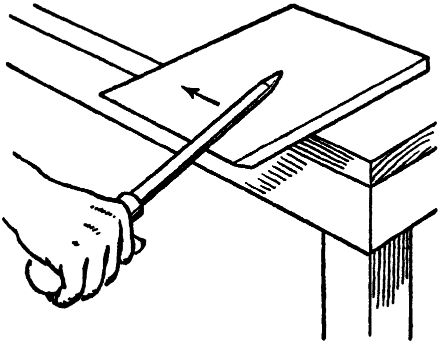


FIG. 1–70. The burnisher is used to smooth the edge of a cabinet-scraper blade.

(See Fig. 1–70.) The burr is turned by a few firm strokes of the burnisher along the bevel side. (See Fig. 1–71.) The first stroke should be made with the burnisher held at an angle a little greater than 45 degrees, and the angle increased on each succeeding stroke until on the last stroke the burnisher is held at an angle of 75 degrees. (See Fig. 1–72.)

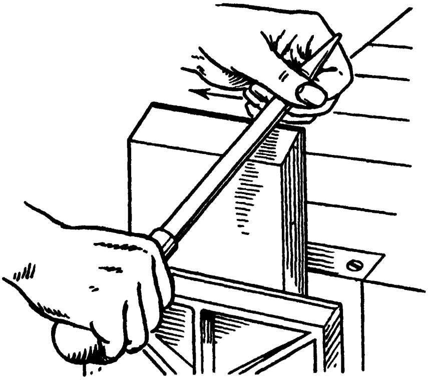


FIG. 1–71. Turning the burr of the blade.

In use, the scraper should be held by the handle and the stock to be worked on held securely by one of the holding tools. The usual procedure is to push the scraper with the blade on the far side of the frame and the adjusting screw facing the operator. It can be pulled toward you provided that the scraper is reversed. Figure 1–73 shows how the scraper is to be used.

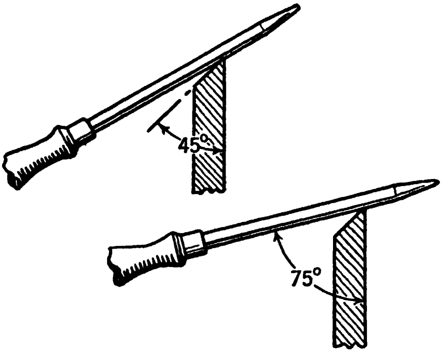


FIG. 1–72. Angles for using a burnisher.

The conditioning of planes. Planes must be kept in condition to do their work properly. With careful handling much uncalled-for grinding and sharpening may be eliminated. In all planes, the cutting edge of the blade projects beyond the bottom of the plane; this means that the cutting edge is exposed at all times. When laying a plane down, place it on its side or with one end on a block of wood to keep the blade from touching the bench top. Planing a surface that has dirt or paint on it or one that has nails driven into it will ruin the cutting edge.

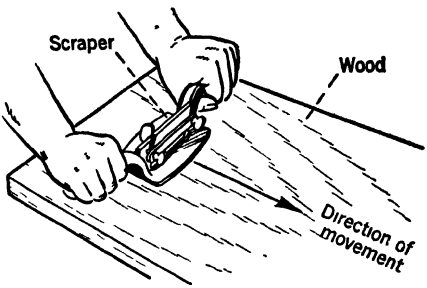


FIG. 1–73 Using the cabinet scraper.

Conditioning a plane iron involves two operations, grinding and whetting. A plane that is dull may not have to be ground to resharpen it. The condition of the cutting edge and the angle of the bevel determine whether a plane requires grinding. A blade that is badly nicked from coming in contact with metal must be reground. Slight nicks may be taken out on an oilstone.

Grinding a plane iron. To grind a plane iron, a grindstone or emery wheel with an adjustable tool rest gives the best results. The tool rest is set up at such an angle that when the plane iron is placed flat on it, the blade will come in contact with the face of the grindstone at an angle of 25 to 30 degrees, as shown in Figure 1 74. The blade is placed on the rest with the edge of the blade in contact with the stone. As the grinding is done, the blade is moved back and forth across the face of the stone.

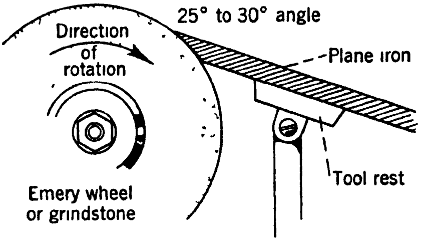


FIG. 1–74. Grinding a plane blade.

Because considerable heat is generated by the blade coming in contact with the stone, a container of water should be kept handy and the blade dipped in it frequently to cool; otherwise the blade will burn and the steel soften, making it impossible for the blade to hold a sharp edge. When a clean straight bevel with the correct angle is obtained, the blade is ready for whetting.

There are several grinding faults which must be guarded against for successful plane-iron conditioning. A bevel that is too long —

that is, one which is at an angle of less than 30 degrees — leaves the cutting edge of the blade weak, with the result that it will nick easily. A bevel that is too short, more than 30 degrees, will have difficulty in cutting into a piece of wood. A plane iron having several bevels, through faulty and unsteady grinding, cannot be sharpened satisfactorily on the oilstone. Such poor grinding may be caused by having too small a tool rest or by not replacing the blade properly on the rest after removing it from the stone for inspection.

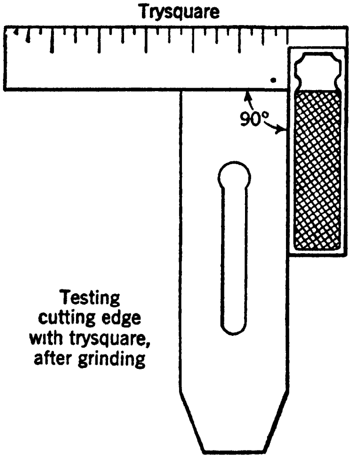


FIG. 1–75. Angles of a plane blade.

The end of the plane iron must be square. It should be tested with a trysquare, as shown in Figure 1–75. If the blade is not kept square to the face of the stone, the cutting edge will not be square.

Whetting a plane iron. The actual sharpening of a plane iron is done on an oilstone. The whetting angle should be 30 to 35 degrees. Place the plane iron on the oilstone, bevel side down, with the end opposite the bevel high enough to permit the blade to come in contact with the surface of the stone at an angle of 30 to 35 degrees.

Hold the blade in both hands, as shown in Figure 1–76*A*. Move the blade back and forth across the face of the stone, keeping your hands and the blade in the same position. Do not raise or lower the edge of the blade during this operation. Continue until a wire edge is turned up on the flat side of the blade. Now turn the blade over and, with the bevel side up, place the flat side on the face of the stone. (See Fig. 1–76*B*.) With both hands on top of the blade, move it back and forth across the stone to remove the wire edge. Complete removal of this wire edge may require repeating these two steps several times.

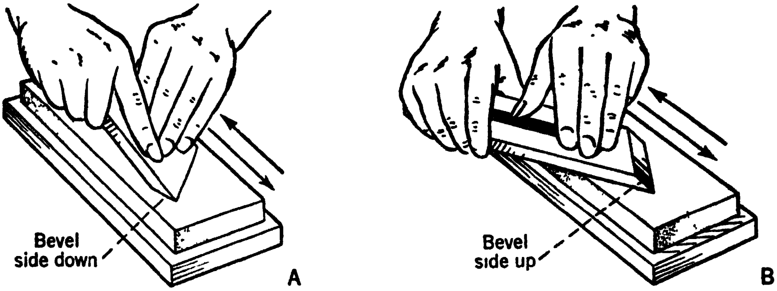


FIG. 1-76. Whetting a plane blade.

The file. The file is a cutting tool made of steel, with teeth cut into the metal. It is used to shape wood or metal. Files are made in various lengths, shapes, and teeth sizes. The length of a file is measured from the point to the heel. (See Fig. 1-77.) The most common shapes are flat, round, half-round, square, and triangular. The flat file is made in lengths ranging from 4″ to 18″; it is rectangular in cross section, tapering both in length and in width. The round file is made in lengths from 4″ to 18″, tapering throughout its length. The half-round file comes in lengths from 4″ to 18″, having one flat side and one curved side; the edges and the convex side are tapered. The square file is square in cross section and its sides are tapered; it can be obtained in lengths ranging from 4″ to 18″. The triangular file is made in lengths ranging from 3″ to 12″; it is triangular in cross section, tapering on all sides from the point to the heel.

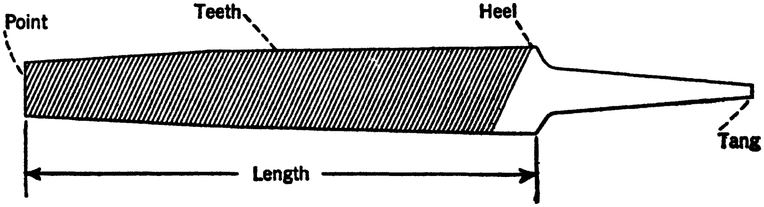


FIG. 1-77. Parts of a file.

The *cut* of a file refers to the character of the teeth. The teeth are formed by a series of parallel cuts at an angle oblique to the length. (See Fig. 1–78.) They may be single- or double-cut. The size of the teeth varies the degree of coarseness or fineness of the cut. The rougher the cut of a file, and the larger the teeth, the greater the space between them. Three cuts are commonly used: *bastard*, *second*, and *smooth*. These are terms which describe the character of the teeth. Bastard has the coarsest teeth; smooth has the finest. A bastard-cut file is used for rough or heavy cutting; it produces a relatively rough surface on the material filed. A smooth-cut file is used for finishing; it produces a relatively smooth surface.

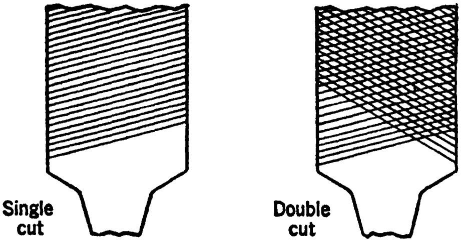


FIG. 1–78. Teeth of files.

A file should be chosen to match the shape of the surface that is to be filed. The tang should be fitted with a handle and secured in place by holding the point of the file up and tapping the handle on the bench.

The work that is to be filed should be held securely in the vise in such a manner that the file, when placed on the surface of the wood, will be horizontal. The point of the file is grasped in one hand and the handle in the other. The file should cut on the forward stroke. Slow, even strokes must be taken, with the file held steady. A lateral movement of the file should accompany the forward motion.

When a file is clogged with filings it can be cleaned with a file card. (See Fig. 1–79.) A few strokes across the file, following the direction of the cut, will loosen any dust that may be lodged in the gullets of the teeth. The wire side of the file card is used when filings in the gullets cannot be removed by the brush. Files are further discussed in Chapter V, "Metalworking," on pages 243–254.

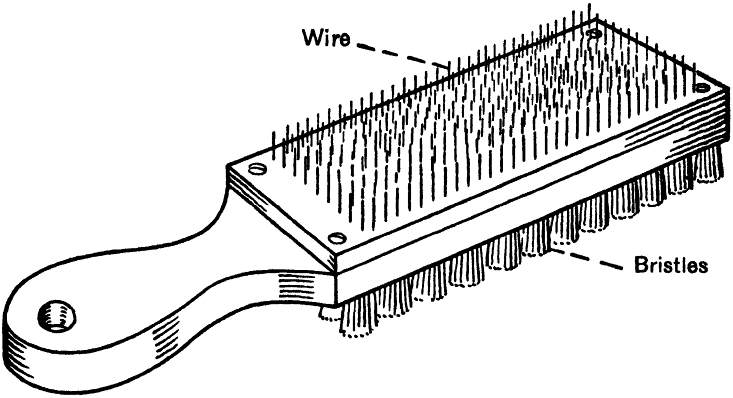


Fig. 1-79. A file card.

The rasp. The rasp is used for rough work when there is a great deal of wood to be removed but not enough to require the use of a saw. A rasp differs from a file in that the teeth are not cut in parallel rows across the metal, but are formed separately. The *half-round cabinet rasp* which the woodworker uses can be obtained in lengths ranging from 6″ to 16″. The degree of coarseness may be second-cut or smooth. The rasp is used in the same manner as the file.

5. HOLDING TOOLS

The woodworker's vise. The woodworker's vise has two jaws, two guide rods, a long threaded screw spindle, a T-head, a yoke, a nut, a handle, and a dog. Vises hold material securely, leaving both hands free for tool manipulation. When sawing, planing, chiseling, boring, or doing any other operation which can be done better with two hands, you will find that the vise is an extremely useful tool.

The purpose of the *jaws* is to hold material between them. Vise jaws should be large in area so that there will be little danger of marking or marring anything placed between them. They should be faced with wood. The *guide rods* keep the jaws parallel at all times. The *long threaded screw spindle* is the means by which pressure is applied between the jaws. The *T-head* is attached to the threaded screw spindle by a rivet. The *handle* fits the T-head loosely to allow the handle to slide freely back and forth in the head. The handle is used to revolve the screw head, which in turn applies the same motion to the threaded rod to open or close the jaws of the vise.

The *yoke* keeps the guide rods parallel and prevents binding; at the same time it provides a bearing for the screw at the rear end. The *nut,* which is set in a housing in the rear jaw, engages the threaded screw. Some vises are equipped with a dog in the front jaw. The *dog* is a piece of rectangular steel set into a recess in the front jaw; it can be raised or lowered. It is used in conjunction with a bench dog, which will be discussed later.

Operation of the vise. There are two types of woodworker's vises, the *continuous-screw* type and the *rapid-acting* type. The continuous-screw type has a solid nut. Its jaws are opened or closed by the continuous turning of the handle. (See Fig. 1–80.)

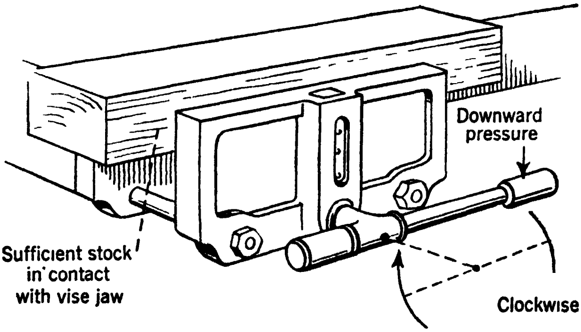


FIG. 1–80. Closing the continuous-screw type of vise.

The handle is turned clockwise to close the vise, and counterclockwise to open it.

One type of rapid-acting vise has a half-nut and a screw with an intercepted thread. The screwhead on this type has a *stop* *pin* which comes in contact with a projection on the outer face of the front vise jaw. This stop allows about three-quarters of a revolution of the handle. In order to open this vise, the handle is revolved in a counterclockwise direction as far as it will go. This brings the two stop pins in line with one another and prevents any further motion of the handle in this direction. In this position, the front jaw can now be drawn away from the back jaw with a slight pull. While the stop pins are in the same position, the jaws may be closed by pushing the front jaw toward the back jaw. The pressure is applied, after the jaws come in contact with the material placed between them, by turning the handle in a clockwise direction.

The other type of rapid-acting vise has a *clutch* arrangement in place of the half-nut. The clutch is disengaged by a reverse motion of the handle, which allows the vise to be opened or closed in the same manner as above. A clockwise motion engages the clutch to apply the pressure.

Oiling the vise. Oiling a vise is a simple matter, and if done regularly many dangers can be avoided. The two important points for oiling are the guide rods and the surfaces where the screw head comes in contact with the front jaw. Guide rods that are not oiled prevent smooth, easy movement of the vise jaws, resulting in undue wear on the threaded rod and nut. Excessive wear on the guide rods or the holes in the rear jaw casting through which these rods pass may throw the jaws out of parallel. This condition will make it very difficult to hold material securely in the vise.

The guide rods and the screw spindle should be kept free of sawdust, and they should be wiped with a cloth occasionally to remove any dust adhering to the oily surfaces. If dust cakes on the guide rods, it is extremely difficult to open and close the vise.

Using the vise. Undue pressure should never be applied to the vise handle, for this may break the handle, the screw head, or the front jaw. If a piece of wood is properly placed in the vise, little pressure is required to hold it securely. When tightening a piece of stock in the vise, apply a *downward* pressure on the handle rather than an *upward* pressure. With downward pressure the most force that can be applied is equal to the weight of your body; this is usually more than is needed. If an upward pressure is used, a greater force can be exerted, and such a force may be great enough actually to tear the bench from its fastenings.

Before using a vise, be sure that the jaws are clean. Small particles of wood, glue, and so on should be scraped off.

A bench equipped with a single vise should have that vise located at the left-hand side of the bench. A vise in such a position is known as a *head vise,* and is used for most of the work involving the use of the vise. (See Fig. 1–81.) When a second vise is located on a single bench, this vise is placed at the right-hand end, and is known as a *tail vise.*

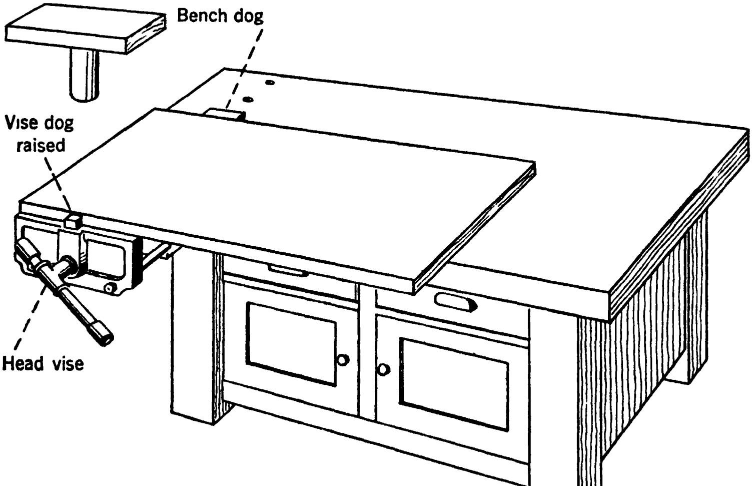


FIG. 1–81. Holding a large piece of stock on the bench by means of a head vise, vise dog, and bench dog. In the upper left-hand corner of the diagram is an enlarged view of the bench dog.

In placing a piece of wood in the vise, certain rules must be followed in order that the stock will be held securely without danger of damaging the vise or the wood. As you probably know, a piece of wood is made up of cells. If too much pressure is applied to these cells, they will be compressed and broken. The greater the area of a piece of wood in contact with the vise jaws, the less danger there will be of breaking down the cell structure. Place the wood in the vise so that as much of the material as possible comes within the faces of the vise; then apply just enough pressure to hold it securely.

There are times when it will be necessary to place a wide piece of stock in the vise with the edges in contact with the jaws. Care must be used when applying the pressure so that the wood will not be bent and split. A short length of wide lumber placed in a vise with the edge of the wood in contact with the jaws will not only split, but it may be thrown out of the vise and possibly hit someone.

If surface planing or sandpapering is to be done on wide stock or glued panels which cannot be placed between the jaws of the vise, such stock may be held securely on the bench top with the aid of the vise and bench dog. (See Fig. 1–81.)

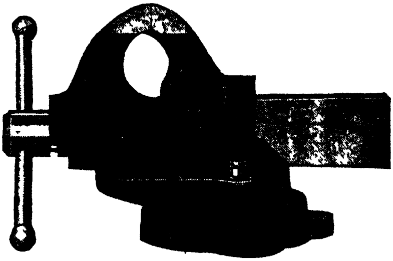


FIG. 1–82. One type of metalworker's vise.

The metalworker's vise. The machinist's or metalworker's vise operates on the same principle as the woodworker's vise, but the entire vise is generally made of metal. (See Fig. 1–82.) The jaws are made of hardened steel, and they may be either smooth or scored for better gripping. If the jaws are scored, work may be protected from them by folding a thin piece of metal over the jaws to separate them from the work.

Safety and the vise. When not in use, the vise should be kept closed with the handle in a vertical position. Vise handles in a horizontal position may project beyond the end of the bench and injure someone.

Proper lubrication of the vise is essential for safety. Vises, particularly the rapid-acting type, that are not properly lubricated will be difficult to open and close, resulting in strain on the vise or the operator.

Improper placement of wood in a vise can often lead to injury. Wood properly placed in a vise will be held securely, and there will be no danger that it will work loose or break while it is being worked. Large pieces of stock insecurely held in the vise may work loose and fall, or throw the operator off balance.

Never use an extra lever to apply extra force to a vise handle. You might break the vise.

Work should be placed low enough in the vise so that the tool operation can be accomplished by the worker without unnecessary stretching. When placing a piece of stock in the vise, make certain that the hand and fingers holding the material are clear of the vise jaws before closing them.

If it should be necessary to stoop down in front of a vise to pick up anything from the floor, be careful not to strike the extending portion of the vise.

The bench stop. The *bench stop*, which is often called a *bench dog*, is made in a variety of types. Some are adjustable for height, and others are of a fixed size. One type of adjustable bench stop consists of a dog which is set into a holder. Such a bench stop may be equipped with a cam.

The *dog* is used as a stop for a piece of wood, as shown in Figure 1–81. It may be used independently or in conjunction with a vise. The *cam*, which is controlled by the screw, holds the dog in any position. If the screw is loosened no more than one turn, the cam is released. The dog may then be lowered or raised if you grasp the plate between the fingers. When a dog is set at the required height, the screw is tightened by pressing the cam against the shaft.

The plate has two sides that are straight, and two sides that are ground and shaped to produce sharp teeth. These teeth should be kept sharp, for they dig into the wood placed against them and prevent slipping. If the dog is to be used with a piece of wood that must not show these toothmarks, the dog may be removed from the holder and turned so that the straight side will come in contact with the wood. The cam and shaft should be oiled occasionally to permit easy operation. The cam should be tightened by means of the screw just sufficiently to hold the dog in position; excessive tightening may break the cam. (See Fig. 1-83.)

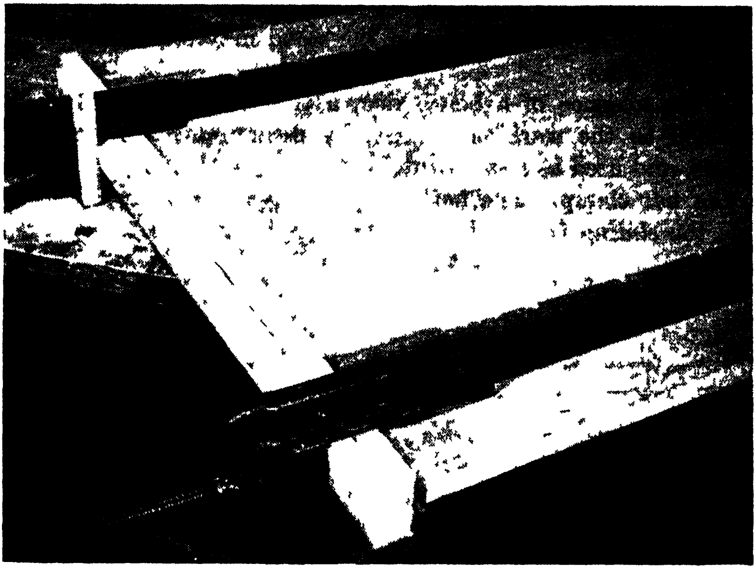


FIG. 1-83. A strip of scrap wood to prevent marring is placed between the head of the jaw and the stock that is being glued.

When planing or sandpapering the surface of a piece of wood that cannot be held in the vise because of its shape or size, the bench stop should be used. When using the bench stop, the dog should be raised just high enough to hold the wood in position. It should always be below the top surface of the stock. Failure to keep these two points in mind may result in splitting the wood or ruining the cutting edge of the plane.

When not in use, the bench stop should have the dog set down into the recess of the holder. A dog with its sharp teeth projecting may cause a serious cut on the hand. A dog with dull or broken teeth should be put back into condition by grinding the teeth to the required shape. Dull teeth will not bite into the wood placed against them, and the wood may shift when being worked.

In the absence of a bench dog, a thin strip of wood can be fastened to the working surface, by means of nails, brads, or screws, and used as a substitute.

The bar clamp. The bar clamp consists of the *bar*, the *head jaw*, the *sliding jaw*, and the *screw*. (See Fig. 1–84.) The head has a threaded shaft which passes through the head casting. To one end of the shaft is attached a metal plate that forms one of the jaws; the other end of the shaft has a crank fastened to it. As the crank is turned, the head jaw is moved. The sliding jaw has a small dog which engages grooves in the bar and maintains its set position regardless of the pressure exerted. Bar clamps can be obtained in various lengths for various uses. We shall discuss here only one common type.

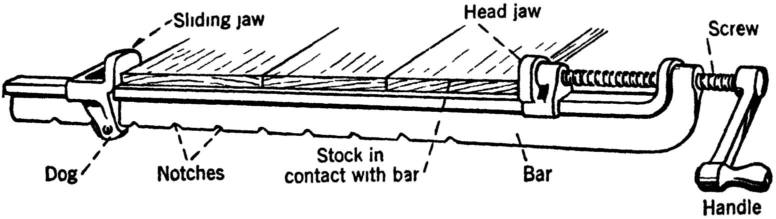


FIG. 1–84. Parts of a bar clamp.

As with all tools with moving parts, lubrication of the bar clamp is necessary. All moving parts, such as the threaded shaft, the socket in the head jaw into which the shaft sets, and the dog in the sliding jaw, should be lubricated occasionally. Since the bar clamp is often used on stock that is being glued together, a certain amount of glue will adhere to the clamp. This should be cleaned off after the clamp has been used. A bar clamp is designed to apply a certain pressure; for this reason the crank is of a fixed length. Excessive pressure produced by using a wrench on the handle will result in the bending or breaking of the handle or sliding jaw.

Bar clamps are used to hold work together during assembly. They can be made to apply a steady pressure between two or more pieces of wood or to hold these pieces securely in their same relative position for an indefinite time. This is especially important when gluing up stock. When bar clamps are applied, the bar should be at right angles to the surfaces of the wood that are in contact with the jaws. Failure to do this will result in the glued-up units being forced out of square. The metal jaws of the clamp should not come into direct contact with the wood members being held together; a piece of scrap wood should be placed between the jaw and the stock. When preparing a bar clamp for use, the head jaw should be brought back as far as possible by turning the handle in a counterclockwise direction. The sliding jaw should be set by releasing the dog, and then moving the head in the proper direction so that the distance between the two jaws is a little greater than the material to be held in the clamp. The dog of the sliding jaw should be engaged in the groove cut into the bar. The clamps should be placed on the stock, with a piece of scrap wood between each jaw and the surface of the stock.

Bar clamps that have the jaws sprung out of parallel should not be used, for they cannot hold securely. The main causes of jaws being forced out of parallel are excessive force used and wear on the bar and sliding jaw.

Emergency clamp. An emergency device that can be used in place of a bar clamp can be made by fastening two blocks of wood to a plank, placing them about one inch farther apart than the length of the stock. The stock is placed on the plank, between the two blocks, and a wedge-shaped piece of wood is driven between it and one of the blocks to hold it tightly in place.

The C-clamp. The *C-clamp,* often called a *carriage clamp,* is used to hold two pieces of work together temporarily. (See Fig. 1–85.) This clamp has a C-shaped frame, one arm of which has a hole drilled and tapped in it, and the other arm of which is flat, forming a bearing surface for the work. A screw passes through the tapped hole in the frame. Fastened to one end of the screw is a swivel head. At the other end of the screw is the handle.

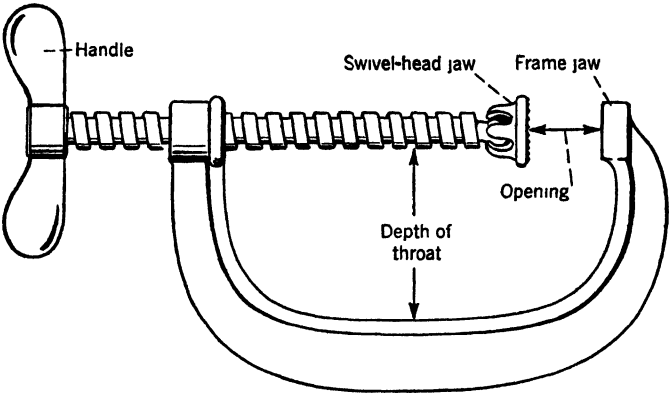


FIG. 1–85. Parts of the C-clamp, or carriage clamp.

The frame which holds the screw forms the connecting link between the swivel head and the frame jaw which comes in contact with the wood. The screw is used to apply the pressure between these two jaws. The swivel-head jaw is attached to the screw by means of a ball-and-socket joint, thereby permitting the turning of the screw without rotating the head when it comes in contact with the wood. The handle is used to turn the screw.

C-clamps come in a great variety of sizes depending on their use. The depth of the throat — that is, the distance between the center line of the screw and the frame — and the maximum opening between the jaws determine the size of the clamp.

C-clamps should be used only as temporary holding devices. The small jaw surface does not cover a great area, and a great amount of pressure will dent the work. The handle of a C-clamp is so small that only the fingers are used to turn the screw; this makes it difficult to exert excessive pressure between the jaws. For such work as sandpapering, the C-clamp is useful to hold a piece of wood to the bench top. The C-clamp can be used to advantage in construction. In boat building, for example, it is used to hold the planks tightly in position against the frame of the boat when driving nails or screws in place.

The handscrew. The *handscrew*, also known as a *parallel clamp*, is used to hold tightly to the bench top, material that is being worked. (See Fig. 1–86.) It is also used to hold two pieces of stock together when being glued. The large jaw provides ample surface to distribute pressure over a relatively large area. There are two types of handscrews, one made entirely of wood and the other with jaws of wood and spindles of metal.

The handscrew has two jaws: a shoulder jaw and a screw jaw; and two spindles: an outside spindle and a middle spindle. The handscrew is adjustable to an angle.

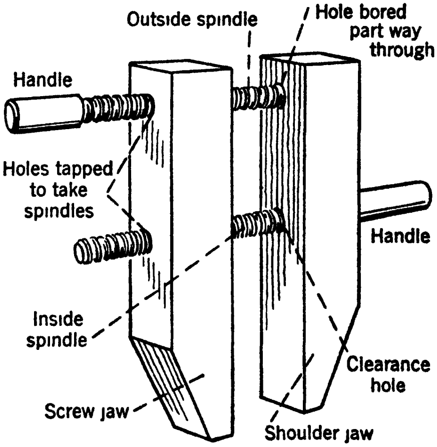


FIG 1–86 Parts of the handscrew, or parallel clamp.

The jaws hold the material between them. The spindles, which are threaded, are used to apply pressure to the jaws. The sockets used within the adjustable clamp permit the closing and opening of the jaws at an angle other than 90 degrees to the spindles.

Handscrews are opened and closed by grasping the handles, one in each hand, and revolving the entire clamp. The left hand grasps the middle spindle and the right hand holds the outside spindle. By revolving the entire clamp around the middle spindle, with the hands holding the spindles securely, the jaws can be opened and closed, keeping them parallel. (See Fig. 1–87.) If one spindle is moved independently of the other the jaw will shift out of parallel. With the all-wood handscrew, this may result in a broken spindle. The adjustable handscrew may have the jaws slanted to hold stock that does not have parallel sides. This can be done up to certain limits; to tip the jaws beyond a certain point will result in bent spindles. When applying or releasing the pressure of the handscrew, the outside spindle should be used first.

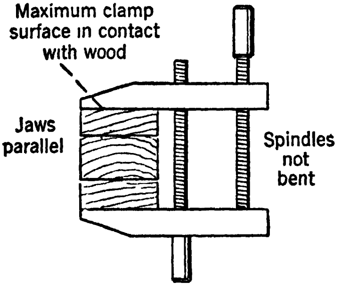


FIG. 1-87. Use of the handscrew.

The handscrew should be opened sufficiently to fit freely on the stock to be clamped together. The handscrew is then placed in position. The middle spindle is turned so that the jaws will come in contact with the stock; then the pressure is applied and the jaws brought back parallel by turning the outside spindle. When applying or releasing the pressure, the outside spindle should be used. When opening and closing a handscrew, hold it far enough from your body so that there will be no danger of striking your face as you revolve the jaws around the middle spindle.

6. SHARPENING TOOLS

The woodworker must not only be familiar with the tools he uses in working wood, but he must also know how to sharpen his keen-edged cutting tools. To sharpen these, he uses a grindstone or a grinder. These grind a new bevel on any keen-edged tool.

The grindstone. The grindstone is a large disc mounted on a shaft, and arranged so that it can be turned by foot power or belt-driven by a motor. This type of stone revolves with relatively low r.p.m. (revolutions per minute). The speed of the stone will vary with its diameter. It should be driven at a speed that will permit 500 to 600 feet a minute to pass the tool that is being ground. This is known as surface speed, and can be determined by figuring the circumference of the wheel in feet, then dividing this figure into 500 to get the r.p.m. If a grindstone is two feet in diameter, the circumference is 6.28 feet. A stone of this size has to turn at 79 revolutions a minute to have a surface speed of 500 feet a minute.

A grindstone must be run with water covering the surface of the stone to carry off the heat being produced in the tool, and to wash off any particles of steel that adhere to the surface of the stone. The disc of a grindstone is made of natural sandstone.

The grinder. The grinder is a tool used for the same purpose as a grindstone but differing in the size of the wheel, the material of which it is made, and the speed at which it revolves. Grinders may be hand- or power-driven. The most common of the power-driven type are those having their wheels fastened directly to the extended shafts of a motor.

The power-driven grinder should be operated at a surface speed of from 5000 to 5500 feet a minute. The handle is attached to a large gear which engages a smaller gear. The shaft on which a smaller gear is placed extends through the casing of the grinder. The stone is fastened to this shaft by means of a nut. The usual gear ratio of this type of grinder is 22 to 1, which means that for every revolution of the handle the shaft on which the stone is mounted revolves 22 times. If such a grinder were equipped with a stone 8″ in diameter, the handle would have to be turned at about 40 r.p.m. to produce a surface speed of 5000 feet a minute.

There are three types of stones commonly used on grinders: emery, silicon carbide, and aluminum oxide. Emery is a natural stone, whereas silicon carbide and aluminum oxide are both produced by the aid of electric furnaces. These abrasives, as the particles themselves are called, are broken up into smaller particles and are graded according to size. The small sizes are used to make stone or fine grit and the larger particles are used for coarser stones

In manufacturing the wheels used in grinders, the abrasive grit is mixed with a bonding agent which is generally a fusible clay

The oilstone. One type of whetstone — or stone used for keen-edged tools — which is used lubricated with oil is an oilstone It is suitable for sharpening metalworking tools as well as woodworking tools The stone may be natural, and made into a convenient shape after being taken from the earth Or it may be fashioned from artificial abrasive materials as in the case of grindstones Among the more usual shapes are rectangular and wedge The artificially made stones are of silicon carbide or aluminum oxide and may be made into wedge, rectangular, oval, round, or other special shapes, depending upon the work required In some cases the oil is not merely placed on the stone but impregnated in it The oil is effective in preventing the stone from getting clogged with tiny particles of the metal The metalworker usually has the oilstone on the top of his bench He holds the tool to be sharpened against the stone, rubbing or honing it against the abrasive surface

The slipstone. A form of oilstone which is shaped and used very much like a file is the slipstone It is made in several cuts and many shapes, depending upon the shapes of the knives or other tools to be sharpened It can be used on steel which would be much too hard to file The machinist usually holds the slipstone in his hand and rubs it over the edge he wants to sharpen or polish Diemakers use slipstones to finish or sharpen die tools of special shapes

When an oilstone is not being used it should be kept covered and soaked in oil, and occasionally it should be scraped off

Emergency substitute. If no whetstone is available and a tool greatly needs whetting, a substitute can be made Wet a flat piece of soft wood and apply a gritty substance, such as a scouring scraper. So prepared, the wood will then be a fairly good hone

B. MACHINE TOOLS

1. THE POWER GRINDER

To perform properly, tools must be ground and shaped. For machine tools, this should be done on a tool grinder. A commonly used type of grinder consists of an electric motor with its shaft extended and adapted to hold grinding wheels. Most tool grinders are equipped with two wheels, one of coarser grain than the other. The coarse-grain wheel is used for roughing down and the fine-grain wheel for finishing.

Safety laws require that guards be placed around the wheels and that transparent guards be placed so that the eyes of the user will be protected from flying particles. In one type of grinder there are simple rests upon which tools may be laid while being ground. Before the power is turned on, these rests should be tested to be sure that they are tight, and they should always be set as close to the wheel as possible. If they are too far from the wheel, the tool being ground may slip and get caught between the rest and the wheel. This is almost certain to nick the wheel and break it. Sometimes special holders are used to hold tools in a fixed position while they are being ground.

In grinding a tool held in the hand, the tool should be kept moving across the face of the wheel to prevent grooving it. When a groove has been worn in a wheel it is necessary to *dress* the wheel. This is done with a *wheel dresser*, which has a set of star-shaped steel wheels mounted in its end. It is used by placing it on the rest and moving it across the face of the wheel while applying an even pressure.

In using the grinder, stand with your head *out* of line with the revolving wheel. Hand-tool grinding is only one of the many uses of grinding wheels. On specially built machines, surfaces can be ground flat and cylinders can be ground inside and out. Hardened-steel parts which no lathe tool can cut can be readily shaped by grinding. By grinding after the piece has been hardened, any deformation due to hardening is corrected.

2. THE DRILL PRESS

The sensitive drill. A commonly used type of drill press is shown in Figure 1–88. It is usually called a *sensitive drill* because pressure is applied to the drill by a lever held in the hand of the operator. The operator learns by experience just how much pressure to apply to insure the most efficient operation of the drill. The sensitive drill is widely used for light work employing the smaller sized drills. In the illustration, the piece held in the vise is being drilled. This vise is specially made for use on a drill-press table. It is so made that its sides are parallel, which makes the vise useful in holding work while drilling holes at right angles to a surface. (See Fig. 1-89.)

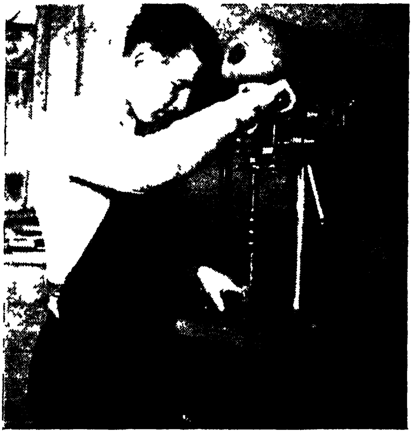


Fig. 1–88. Use of a sensitive drill press.

The power-fed drill press. When heavy drilling is done, a power-fed drill press is used. In this drill press, power is used to feed the drill into the work. This is done by a series of gears which are driven from the shaft which drives the drill. In the sensitive drill, the operator determines the rate at which the drill is fed into the work by the amount of pressure he applies. In the power-fed drill the rate at which the drill advances into the work is determined by meshed gears in the driving mechanism. The operator may bring different gears into mesh by using levers, much as in shifting the gears of an automobile.

In heavy drilling, work must always be strapped to the table of the drill press or held securely by some other means. If the work moves out of line it may be ruined, and someone may be

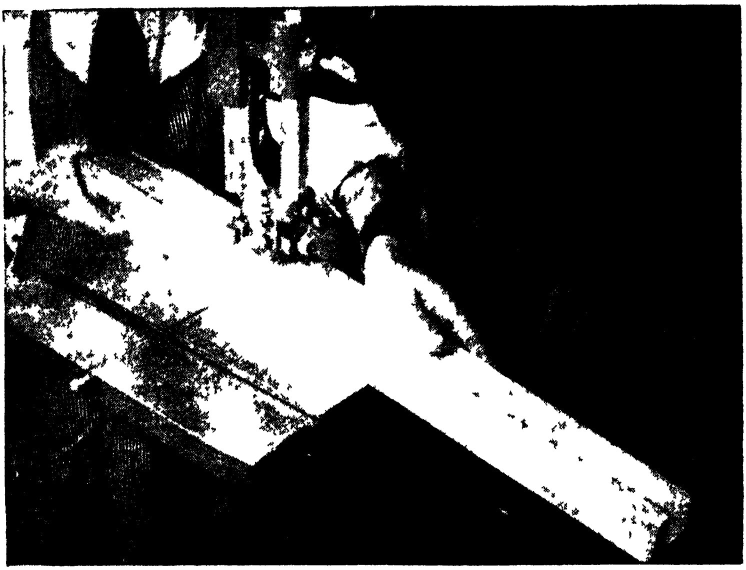


FIG. 1–94 Using a band saw to cut a taper on a piece of stock.

crease the number of times the tool has to be ground. As each grinding uses up part of a tool, frequent whetting will prolong its life.

SUMMARY

1. Tools are used to convert raw materials into useful articles.
2. A worker must know what the different tools are, what they can and should be used for, and how to use them properly.
3. The care of tools consists of storage, use, and conditioning. Proper care of tools is essential to safety and maximum efficiency.
4. Tools are either hand-driven or power-driven. Power-driven tools are called machine tools. Most tools used for metalworking are machine tools.
5. Hand tools may be classified according to their use as layout tools, boring tools, driving tools, cutting tools, and holding tools.

6. Common layout tools are the pencil and knife, the rule, the trysquare, the framing square, the T-bevel, the marking gage, the divider, the trammel, and the compass.

7. Common boring tools are the hand drill, the bit brace, and the various types of bits, the countersink, the twist drill, and the brad awl.

8. Common driving tools are the hammer, the mallet, and the nail set.

9. Common cutting tools are the various types of saws, the various types of chisels, the gouge, the sloyd knife, the various types of planes, the file, and the rasp.

10. Common holding tools are the vise, the bench stop, and the various types of clamps, including the hand screw.

11. Common sharpening tools are the grinder, the grindstone, the oilstone, and the slipstone.

12. The most important machine tools are the power grinder, the drill press, the lathe, the shaper, and the drilling machine.

How many of the following terms and phrases can you define or explain?

Hog in
Choking
Ferrule
Chuck
Tang
Knurled
Metric system
Calibrated
Trysquare
Flute
Sweep
Saw kerf
Bevel
Whetting
Eccentric
Scribe
Faceplate
Slack stroke
Dresser
Caliper
Countersink
Dado

SELF-TESTING EXERCISES

Answer These Questions

On a separate sheet of paper numbered from 1 to 5 write the letters for the phrases that answer the following questions correctly.

1. Which of the following tools are used to draw or scribe lines on wood? (*a*) Pencil; (*b*) rule; (*c*) T-bevel; (*d*) marking gage; (*e*) knife.

2. Which tool would you use to lay off one dimension a number of times? (*a*) Rule; (*b*) marking gage; (*c*) transfer divider; (*d*) compass; (*e*) trammel.

3. Which one of the following bits would you use for boring holes in thin stock? (*a*) Auger bit; (*b*) expansive bit; (*c*) Foerstner bit; (*d*) twist bit; (*e*) gimlet bit.

4. Which tool would you use for boring very small holes in metal or wood? (*a*) Auger bit; (*b*) expansive bit; (*c*) Foerstner bit; (*d*) twist bit; (*e*) gimlet bit.

5. Which tool is used for the final smoothing operation before sanding? (*a*) Scraper; (*b*) combination plane; (*c*) file; (*d*) rasp; (*e*) router.

COMPLETE THESE STATEMENTS

On a separate sheet of paper numbered from 1 to 20 write the words needed to fill correctly the blank spaces in the following sentences.

Mass production has been made possible by the use of (1) -driven precision machines. A pencil may be used for drawing (2) lines on wood. To convert a metric measurement to inches, multiply the number of millimeters by (3) . The T-bevel is used to test and lay out angles other than (4) degrees. The bit most often used by the woodworker is the (5) bit. Twist bits and twist drills are sharpened on a (6) . The purpose of the set of the saw is to make the saw-kerf slightly (7) than the thickness of the blade. The framing chisel has a (8) blade than the paring chisel. Sharpening a knife consists of three operations, removing (9) , (10) , and (11) . The block plane is set so as to meet the wood at a (12) angle than the smooth plane. Conditioning a plane involves two operations, (13) and (14) . To perform properly, tools must be (15) and (16) . In grinding a tool held in the hand, the tool should be kept moving across the face of the wheel to prevent (17) . The most widely used machine tool is the (18) . The shaper does not cut on the (19) stroke. The profile of the (20) of the milling machine determines the shape of the cut made.

ARE THESE TRUE OR FALSE?

On a separate sheet of paper numbered from 1 to 10 write a T *or an* F *to show whether each statement is true or false.*

1. The marking gage may be used to scribe lines parallel to the edge or face of a piece of wood.

2. When a machinist speaks of boring a hole he means enlarging or truing up a hole which has already been made.

3. The rotation of a crank may be reversed while drilling a hole.

4. The jaws of the chuck on a brace are opened by revolving the shell in a counterclockwise direction.

5. When using a hammer you should grasp it firmly near the middle of the handle.
6. The head of a nail set should be kept square.
7. The hacksaw is used for cutting metal.
8. The paring chisel is used for rough carpentry work.
9. In heavy drilling, work must be strapped to the table of the drill press or held firmly in some other way.
10. The shaper is used to peel off metal from a flat surface.

QUESTIONS

1. Why should idle tools not be left on a bench top or on the floor?
2. Do you have more reason to be afraid of sharp tools or of dull ones? Why?
3. What graduations are usually shown on a rule calibrated by the English system? What graduations may be shown on it for greater accuracy?
4. What graduations are shown on a rule calibrated by the metric system?
5. What are the two important uses of the trysquare?
6. For what purposes are dividers used?
7. What are the two most common types of bit brace?
8. What is the proper way to hold and use a hammer when driving nails?
9. Which kind of saw is most commonly used by the carpenter to cut timbers, planks, and boards?
10. What are the two most important uses of the woodworker's chisel?
11. What are the three important operations in sharpening a knife?
12. What is the purpose of the jaws of the woodworker's vise? The guide rods? The long threaded rod?
13. What are the three main parts of the bar clamp?
14. What is a slipstone? For what is it used?
15. Describe a commonly used type of power grinder.
16. Why is a sensitive drill so called?
17. In a power-fed drill, what determines the speed with which the drill advances into the work?
18. What are the common uses of the lathe?
19. What is the shaper used for?
20. How is work fed against the cutter in a milling machine?

11

Common Essential Tools

A. THE KNIFE

Of all the various types of tools used, the cutting tool is probably the oldest; of the various kinds of cutting tools, the knife is the one most commonly seen and used. Through the years, because of different requirements, knives have been devised in a great variety of sizes and shapes — for use by the butcher, by the tailor, by the electrician, in the home, and so on.

1. PARTS OF THE ELECTRICIAN'S KNIFE

One kind of knife used in a great variety of jobs by the Army is the *electrician's knife*. To men who have had training as boy scouts, the knife will look familiar, for it has the general appearance of a simplified boy scout's pocketknife.

The electrician's knife has three parts: a *frame*, which also acts as the handle, a *cutting blade*, and a *screwdriver blade*. When in use, the screwdriver blade is locked into place. This prevents the blade from shutting suddenly against the fingers and from giving way and sliding off the screw head.

The screwdriver blade and the cutting blade should never be open at the same time. The old-type electrician's knife has a screwdriver blade that is unlocked by pressing on the back of the cutting blade when that blade is closed. In the new-type electrician's knife there is a different type of locking mechanism. When the screwdriver blade opens, a spring pushes over and catches under a part projecting from the front of the screwdriver blade. Since the grip on the handle may increase as pressure is applied to the screwdriver, this newer type is much safer than the old type; on the old type, increased pressure on the handle can release the lock and cause serious injury to the worker.

2. CARE OF THE KNIFE

Oil and rust. The same general care should be given the knife as is given any other tool. The metal should always be covered with a thin layer of oil as a protection against rusting. This is easily done by wiping with oiled cotton waste or rag. If rust does get on any part of the knife, it should be quickly removed by rubbing with fine emery cloth and then wiping with an oiled rag. Occasionally a drop of oil should be placed on the pivot on which the knife and screwdriver blades move.

Shaping the blade. The cutting blade of the knife is a *double-beveled tool;* that is, both sides of the blade slope to form the cutting edge. The woodworker's chisel, for example, is a *single-beveled tool;* only one side slopes to form the cutting edge, and the other side comes straight down to join the sloping side to form the cutting edge.

The knife is made of low-temper steel; that is, it will lose its temper or hardness if exposed to too great a heat. Never grind the knife on a carborundum wheel to remove nicks or re-form a broken point, for a carborundum wheel generates a high temperature. This can be easily seen by grinding a thin piece of low-temper steel on such a wheel. If the metal is not frequently removed and dipped into water to reduce the temperature, the steel will quickly lose its temper and *burn*, or turn black.

The grindstone should be used to remove nicks and reshape the cutting blade and the screwdriver blade. (See Fig. 1–52, page 52.) With this stone the blade cannot be burned. The water on the grindstone serves to reduce the heat generated by the friction of grinding.

Sharpening the blade. After all the nicks have been removed and the blade is reshaped, hone (whet) the knife on an oilstone. Be sure that there is a light oil on the stone, for this prevents the burrs removed from the metal from sinking into the stone. If the oil becomes muddy, wipe it off with a rag and replace it with clean oil.

Hone the knife by stroking first one side of the blade and then the other. Be sure this is done so that only the cutting edge actually meets the stone. Do not hone in one spot, but work the knife over the entire surface of the stone with a motion similar to that shown in Figure 2–1. Keep the blade at an angle of 20° with the stone to obtain the proper bevel — a long bevel, never a short blunt bevel — and hone until the required degree of keenness is obtained. A test for this is to place the edge of the blade carefully on the thumbnail. Press just a little and draw the blade *carefully* along the nail. If it *slides* over the nail, it is not sufficiently sharpened; if it seems to *cling* or *grab*, it is sufficiently keen

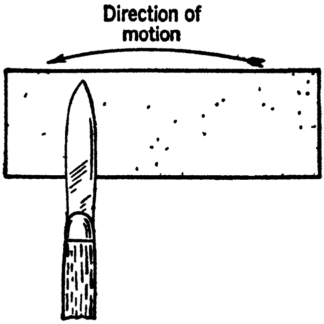


Fig 2–1 Sharpening the blade of a knife.

The method of sharpening and shaping the screwdriver blade is similar to that for any screwdriver (See pages 102–103) One long side of the screwdriver blade is fairly sharp; it should never be made keener than it was when it was new.

After using the electrician's knife, wipe it clean with an oily rag If it is not to be used for some time, store it with a protective coating of heavy grease

Emergency knife care. If a knife must be sharpened when there is no oilstone available, a temporary (and less satisfactory) edge can be put on it by honing it on any flat, smooth stone. Follow as closely as possible the instructions given above. Lacking an oily rag, a knife can be cleaned reasonably well by plunging it several times into the earth.

3. USE OF THE KNIFE

The electrician's knife can be used for a variety of purposes, but chief among these are: (1) whittling soft materials; (2) cutting rope, twine, and the like; (3) removing insulation from electric wires; and (4) scraping electric wires clean with the screwdriver blade. These uses will be discussed in detail later.

4. SAFETY IN USING THE KNIFE

The general rules of safety for using any hand tool apply in using the electrician's knife. However, special attention is called to the warning that when using any cutting blade, the direction should always be *away* from the body. A little thought will show how practical this warning is. If the knife slips while cutting away from the body, injury to the operator is unlikely; but if the knife is used for cutting toward the body, the slightest slip may cause a serious injury. When someone is working with you or near by, extra care must be exercised to avoid injuring him in case of a slip.

If you use the older type of electrician's knife, be careful that pressure on the handle does not allow the screwdriver blade to get unlocked and close. And while using the cutting blade, be sure that there is no chance of the blade's folding up suddenly and catching a finger.

B. THE SCREWDRIVER

1. PARTS OF THE SCREWDRIVER

The screwdriver is used to drive screws and to remove them. These are made in a variety of styles, such as the *plain, ratchet, offset,* and *spiral.* (See Figure 2–2.) The screwdriver consists of a *blade,* the tip of which is shaped to fit the slot in the head of a screw, and a *handle,* which may be part of the blade, as in an offset screwdriver, or may be made of wood or some other material fastened to the blade by means of rivets.

The sizes of screwdrivers are determined by the length of the blade, which is measured from the tip to the beginning of the ferrule, as well as by the width of the tip. Blade lengths range

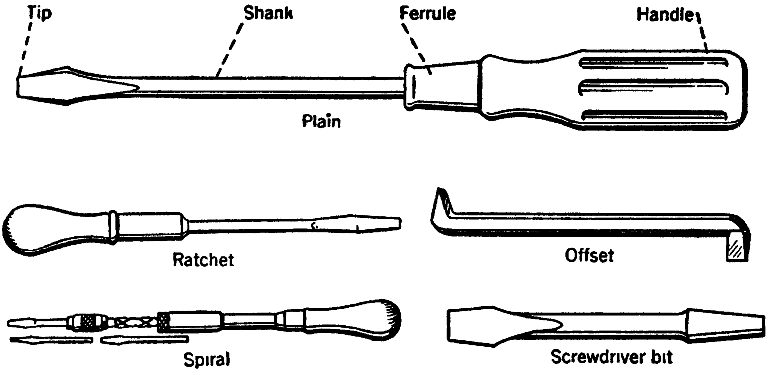


FIG. 2–2. Types of screwdrivers.

from $1\frac{1}{2}''$ to $18''$, and the widths of the tip range from $\frac{3}{16}''$ to $\frac{1}{2}''$. These sizes apply to screwdrivers that are used to drive screws with a single slot in the head.

The Phillips screw must be driven with a screwdriver having a specially shaped tip. (See Fig. 2–3.) The tips of these screwdrivers are sized by numbers. The #1 tip is used for #4 screws or smaller. The #2 tip is used for #5 to #9 screws. The #3 tip is used for #10 to #16 screws. The #4 tip is used for #18 and larger screws.

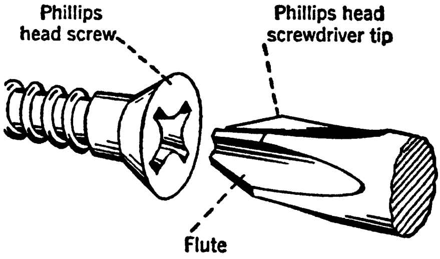


FIG. 2–3. Phillips head screw and screwdriver tip.

The screwdriver tip. The choice of the correct tip to use when driving a screw is of the utmost importance. The tip should fit snugly in the screw slot and should not extend beyond the head. (See Fig. 2–4.) One that is too wide will extend beyond the head of the screw and scar the wood as the screw is driven in. The sides of the tip that come in contact with the side of the screw slot should be parallel to insure a positive grip. The end of the tip should be straight. If it is round or beveled, it will rise out of the slot and ruin the screwhead. It will be found that the longer a screwdriver is, the more force can be applied; therefore, use the longest screwdriver convenient for the work.

2. CARE OF THE SCREWDRIVER

The care of a screwdriver involves proper use of the tool. A screwdriver is designed to drive or remove screws having slotted heads, and it should not be used for any other operation. If you use a screwdriver to pry open crates, to separate two pieces of wood, and so on, you are likely to bend the shank. This throws the tip out of center in relation to the handle, and the tool is then no longer safe to use as a screwdriver.

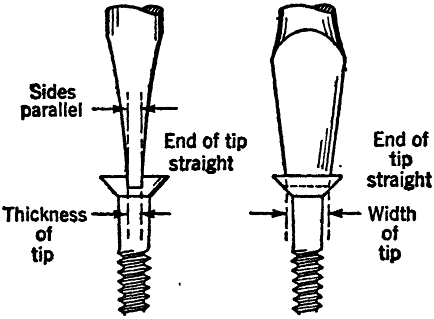


FIG. 2-4. The choice of a screwdriver tip depends upon the head of the screw to be driven.

The choice of the correct size tip to fit the slot of a particular screw is another factor in the care of the screwdriver. If the proper size of screwdriver is always used, the need for reconditioning the tip will be reduced considerably. While a screwdriver is not a keen-edged tool, the same protection should be given it as should be given a cutting tool. A screwdriver that is dropped or misused requires frequent reconditioning, which is wasteful of time and material.

A screwdriver tip that does not have its proper shape should be put back in condition by grinding the blade. The tip of a screwdriver blade is first ground straight and square on the grindstone. The thickness of the tip at the end must be equivalent to the width of the slot in the screw that is to be driven. The flat surfaces on each side of the shank should be ground slightly concave so that they will be parallel at the end which fits into the screw slot. It is important to have the shape of these flat surfaces alike so that the tip will be on the center line of the shank.

3. USE OF THE SCREWDRIVER

When driving screws, the screw is generally placed in a hole which has been bored for it. The screwdriver is held with one hand over the end of the handle and the other hand on the stock with the thumb and first finger hooked around the blade to steady it. (See Figs. 2-5 and 2-6.) A downward pressure should be applied to the handle, twisting the hand at the wrist in a clockwise direction at the same time. The screwdriver must be held parallel to the vertical axis of the screw; it should never be tilted, for the tip may slide or jump out of the slot. After the screw has

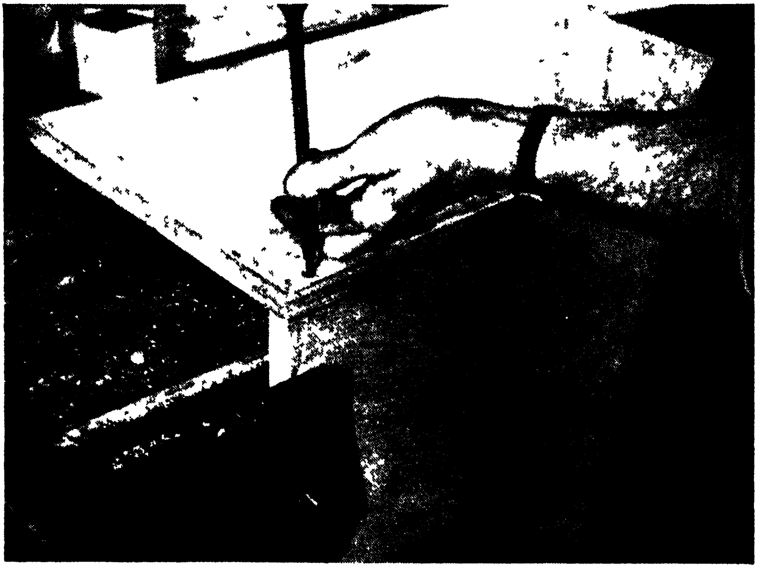


FIG. 2-5. The worker is steadying the screwdriver with his left hand while driving it with his right hand.

taken hold, the hand that was guiding the tip should be moved up and placed around the shank. This is a safety measure, for if the tip should slip out of the slot it might cut the hand.

To remove screws, the same procedure should be followed except that the screwdriver is turned in a counterclockwise direction, and only enough pressure is used to hold the screwdriver in place.

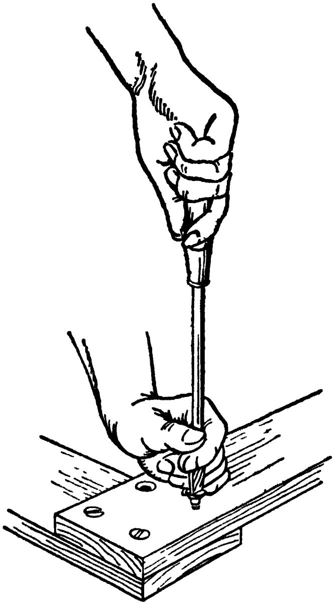


FIG. 2-6. Use of the screwdriver.

4. SAFETY

There are certain rules that must be observed by a person handling, using, or carrying a screwdriver to prevent injury to himself or damage to the work being assembled. A screwdriver tip should be of such shape and size as to fit the screw slot snugly. If such a screwdriver is not available, the one to be used should be shaped to fit. Failure to do this may result in damaging the screw slot to such an extent that the screw can be neither driven nor extracted. A screwdriver tip of the wrong shape and size may also cause the tool to slip out of the screw slot and damage the work or some vital piece of equipment near by. When the downward, twisting pressure is applied to a screwdriver, there is no way of controlling the screwdriver if it should slip out of the screw slot.

When a screwdriver is used it must be kept in line with the axis of the screw and centered in the slot. Any shifting of the blade in its relation to the center of the head and the axis of the screw will result in its slipping out of the slot. A bent screwdriver blade cannot be kept in line with the axis of the screw and therefore should never be used.

Although a screwdriver is not classed as a sharp cutting tool, it can do serious injury to a person if not used with the proper care. When using a screwdriver keep your hands behind the tip of the blade. It is a dangerous practice to place one hand behind the work to support it while the screwdriver is held and used in the other hand. If the screwdriver should slip it is very likely to do serious damage to the hand in front of it.

Never carry a screwdriver in your pocket; if you should fall it is likely to stab you. Carry it in the tool box or in your hand with the tip down.

Emergency substitutes. Although whenever possible the correct tool should be used for every job, there may be times when a screwdriver, for example, is not to be had, yet a screw must be tightened or removed. A coin, a washer, the head of another screw, and such implements can be substituted for a screwdriver in an emergency.

C. PLIERS

Vises, clamps, and pliers are holding tools. Of these, pliers are most commonly used, especially by workers in electrical trades.

1. TYPES OF PLIERS COMMONLY USED

Pliers come in a great variety of types and sizes, each designed for a particular job. The inexperienced workman may attempt to use one kind of pliers for a job that should be done by another kind or to use pliers as a wrench or hammer. Pliers are not an all-purpose tool; they should be used only for the particular purpose for which they were designed.

Pliers are usually classified by the length and shape of the jaws, as 6″ side-cutting or 4″ diagonals. The kinds of pliers most often used are the *side-cutting pliers,* the *long-nose pliers,* and the *diagonal pliers.* (See Fig. 2–7.) (*Nose* always refers to the business end of tools, as the jaws of pliers.)

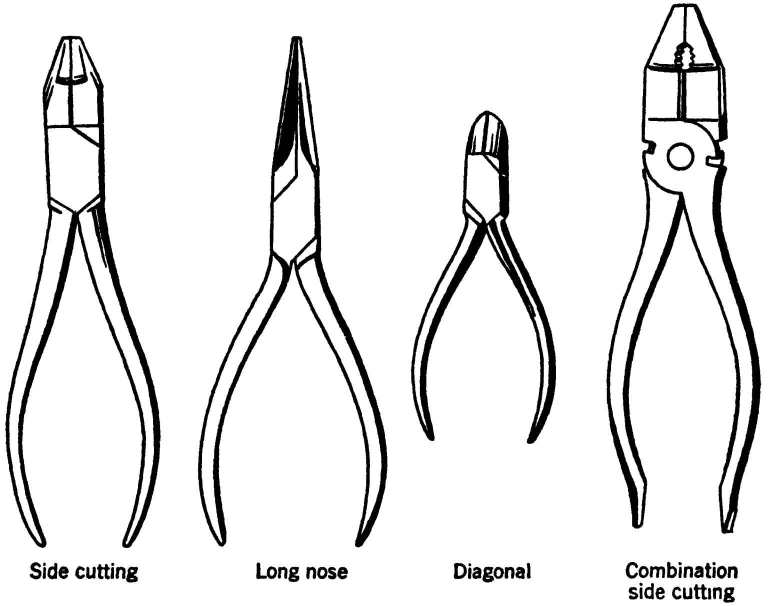


FIG. 2–7. Types of pliers.

2. USE OF SIDE-CUTTING PLIERS

Side-cutting pliers, also called *lineman's pliers,* are used for gripping, wire splicing, wire cutting, insulation stripping, and (by using the heel) for crushing insulation. The most useful sizes are 6″ and 8″; larger sizes are used for handling heavier wire. Side-cutting pliers are blunt nosed. The front ends of the jaws have a *scored gripping surface* which is a surface roughened with a series of grooves running from side to side and very close together. Behind the gripping surfaces are *cutting blades;* they have parallel heel surfaces and strong handles. (Note, however, that Army publications state that in aircraft work it is not advisable to skin wires with pliers of any kind.)

When removing insulation, the jaws of the pliers should not be allowed to touch the bare wire. If this happens, the wire may become nicked and therefore weakened; or some of the metal may be removed, thus reducing the diameter of the wire.

Side-cutting pliers should never be used for cutting completely through solid wire, for this may damage them. The proper method is to cut only *part way* through, making a deep nick in the wire. Then use the gripping end of the jaws to bend the wire back and forth at that point until it breaks.

3. USE OF LONG-NOSE PLIERS

Like side-cutting pliers, long-nose pliers have a variety of uses, such as gripping, reaching places not readily accessible to the fingers, holding wires, bending loops, attaching wires to terminals and punchings, and skinning and splicing small wires.

The most useful sizes of long-nose pliers are the 5″, 5½″, 6″, and 6½″. They have long, narrow, tapering jaws, half-round on the outside and flat on the inside. Usually these inside flat surfaces are scored near the end of the pliers. Some long-nose pliers have side-cutters behind the gripping surface of the jaws. If the long-nose pliers have no side-cutters, they can be used for crushing wire insulation. This is done by sliding the wire down the base of the jaws and squeezing the handles, thus loosening the insulation so that it can be removed easily from the wire. If necessary, the gripping surfaces of the jaws can be used for cleaning the wire.

Long-nose pliers are delicate tools. They should not be misused by being forced to do heavier work than that for which they were planned. Never use them for holding large and heavy objects, for tightening nuts, or for bending heavy gages of wire and sheet metal; for if this is done the jaws will become separated and out of alignment, rendering the pliers useless.

4. USE OF DIAGONAL PLIERS

Diagonal pliers, also called simply *diagonals*, are used only for cutting wire. The most useful size is 5″. The jaws of diagonal pliers consist of two cutting edges set at an angle of 15 degrees to 20 degrees with the length of the pliers. They are superior to the side-cutting pliers because they can cut off wire closer to its point of attachment. Diagonal pliers are used only for wires up to #16 hard steel or #14 copper. Wires harder and heavier than these should be cut with side-cutting pliers.

SUMMARY

1. Three of the common essential tools used in the shop are the knife, the screwdriver, and the pliers. They illustrate, respectively, cutting tools, driving tools, and holding tools.
2. The electrician's knife has a cutting blade and a screwdriver blade, making it a dual-purpose tool. Each blade is used in a different manner, and both should not be open at the same time.
3. The knife blade should be shaped on a grindstone and honed on an oilstone. Rust on the blade can be prevented by a thin coat of oil, and removed with a fine emery cloth.
4. The electrician's knife is used for whittling soft materials, or cutting rope and twine, for removing insulation from electrical wires, and for scraping wires clean.
5. In using the knife, cut away from your body. Be sure that the blade cannot fold on your finger while you are using it.
6. The screwdriver is used to drive screws and to remove them. For any job, select a screwdriver which has a tip that fits exactly into the head of the screw to be driven or removed. The longer the screwdriver, the greater the force that can be exerted.
7. The screwdriver should be shaped on a grindstone. Its flat surface should be slightly concave; the sides parallel for the depth of the screw slot; and the tip centered, square, and uniform in thickness.
8. When driving screws, place the screwdriver tip in the head of the screw, parallel to the length of the screw. A downward pressure and a clockwise twisting will drive the screw; to remove a screw, twist in a counterclockwise direction and use only enough pressure to hold the screwdriver in place.

9. The most common types of pliers are the side-cutting, the long-nose, and the diagonal. Each has its particular use.

10. Side-cutting pliers are used for gripping, wire splicing, wire-cutting, insulation stripping, and crushing insulation.

11. Long-nose pliers are used for gripping, reaching inaccessible places, holding wires, bending loops, attaching wires, and splicing wires.

12. Diagonal pliers are used for cutting small wires and for cutting wires in tight places.

How many of the following terms can you define or explain?

Cutting tool
Electrician's knife
Double-beveled
Low-temper steel
Hone
Screwdriver
Phillips screw
Linesman's pliers
Scored gripping surface
Long-nose pliers
Diagonals

SELF-TESTING EXERCISES

ANSWER THESE QUESTIONS

On a separate sheet of paper numbered from 1 to 4 write the letters for the phrases that answer the following questions correctly.

1. How is the cutting blade of the electrician's knife shaped? (*a*) It has no bevel; (*b*) it has a single bevel; (*c*) it has a double bevel.
2. How should the knife be reshaped after nicking? (*a*) It should be ground on a grindstone; (*b*) it should be ground on a carborundum wheel.
3. Which of the following characteristics makes a screwdriver desirable? (*a*) A rounded tip; (*b*) flat surfaces of the tip slightly concave; (*c*) a curved shank.
4. Which type of pliers should be used to remove insulation from large wires? (*a*) Side-cutting pliers; (*b*) long-nose pliers; (*c*) diagonal pliers.

COMPLETE THESE STATEMENTS

On a separate sheet of paper numbered from 1 to 16 write the words needed to fill correctly the blank spaces in the following sentences.

Three of the most common essential tools are . (1) . ., . . (2) ., and . . (3) . . . The electrician's knife consists of . . (4) . ., . . (5) . ., and . . (6) . . . It is used as a . . (7) . . tool and as a . (8) . . tool. The knife should be ..(9).. on an oilstone, keeping it at an angle of ..(10).., to obtain a ..(11). bevel. Selection of the proper screwdriver for a job depends greatly upon the size of the screwdriver . (12)... The ..(13) . the screwdriver, the more power that can be applied. To drive a screw, twist the screwdriver in a .(14) direction. Pliers are classified as ..(15).. tools. Heavy wires should be cut with the ..(16).. pliers.

ARE THESE TRUE OR FALSE?

On a separate sheet of paper numbered from 1 to 6 write a T *or an* F *to show whether each statement is true or false.*

1. Pliers are classified as holding tools.
2. Knife blades should be honed on an oilstone.
3. A carborundum wheel should be used for grinding the edge of an electrician's knife.
4. The longer the screwdriver, the greater the force that can be exerted.
5. Pliers are correctly used as driving tools.
6. Diagonal pliers should be used to cut heavy wires.

QUESTIONS

1. Why are there so many different kinds of knives?
2. What is a recent improvement in the electrician's knife? Why is it an important change?
3. How can you prevent rust from forming on metal? How can rust be removed from a knife?
4. What is a double-beveled tool? Give an example of one.
5. Why is a grindstone, rather than a carborundum wheel, generally used to shape a knife? How does water help the grinding?
6. How should an electrician's knife be honed?
7. What is the Phillips screw, and how is it driven?
8. Why should the screwdriver be held parallel to the length of the screw it is driving?
9. How do you remove a screw that has been incorrectly screwed into place?
10. How are pliers classified? What kinds have you just studied in this unit?
11. What is a scored gripping surface? What is its value?
12. How should you cut solid wire, using the side-cutting pliers?
13. What are three reasons for always using the tool designed for the work?

III

Measuring and Gaging

When we want to make something it is necessary to know what is to be made, what its form is, how thick it is, how long it is, and how high it is. The size and shape of its various parts must be known. Usually this information is conveyed to us by means of a drawing or sketch. Such a drawing is called a *detail drawing;* generally it appears in the form of a blueprint, which is a reproduction of a drawing. The size and location of everything that enters into the making of the part is shown in these drawings, sketches, or blueprints. The draftsman calls the indication of distances between points *dimensioning.* When making the part, the workman is guided by these dimensions.

A. THE STEEL SCALE

1. GRADUATIONS

The *steel scale* is important in using these dimensions. It resembles the wooden ruler, and uses the same units. Steel is used because fine lines can be marked on it. It can be tempered to be flexible or stiff as required, with a surface hardened to resist wear; and its shape and size are not affected by moisture. Stainless steel is also coming into use, because it combines the other good properties of steel with the ability to resist corrosion.

In Europe, steel scales are marked off in centimeters and multiples and divisions of the centimeter. If you were working from a drawing made in Europe, you would find it convenient to use one of these scales employing the metric system. The advantage of the system is that all its units are evenly divisible by 10. Attempts have been made, and are being made, to bring the metric system into more general use in the United States; but at present, in English-speaking countries the inch is the most commonly used unit of measurement.

The inch unit or English scale. You probably have little trouble with the multiples of the inch. You know that there are 12 inches in a foot, and that there are 3 feet in a yard. But when you come to the divisions of the inch, you may have some difficulty. A study of a 6-inch scale will help.

First, think of the scale as divided into 6 parts. Each part is 1 inch long. (See Fig. 3-1.) Select any one of these parts; for example, the inch between 3 and 4. (See Fig. 3-2.) Note that one line, longer than the others, divides the inch into two parts, each one-half inch long.

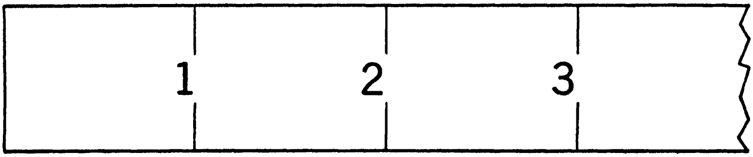


FIG. 3-1.

Next, look for two shorter lines, equal in length to each other, which divide each of these halves into 2 parts. (See Fig. 3-3.) Each of these parts is one-quarter inch long.

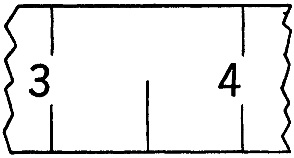


FIG. 3-2.

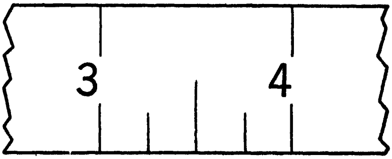


FIG. 3-3.

These are again halved by lines. (See Fig. 3-4.) These new dimensions are half of one-quarter, or one-eighth inch long. The eighths are next halved to make sixteenths, then the sixteenths to make thirty-seconds, and these to make sixty-fourths. (See Fig. 3-5.)

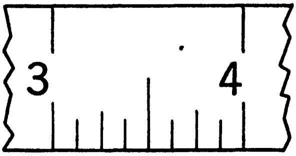


FIG. 3-4.

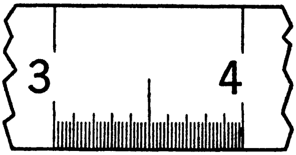


FIG. 3-5.

Note that as the divisions become smaller, the number under the line of the fraction (the denominator) becomes greater. Not only does it become greater, but every time it doubles, the distance it measures is halved. A much-used scale is one which on one side uses one edge to divide the inch into eighths and the other edge for sixteenths. On the other side of this scale, the inch is divided into thirty-two parts on one edge and sixty-four on the other.

2. USE OF THE STEEL SCALE

Suppose, using this scale, you proceed to lay off a distance of $3\frac{3}{16}$ inches. First, turn to the edge divided into sixteenths. After the inch marked 3 it is easy to count off 3 one-sixteenth divisions and find your measurement. Suppose, however, you wish to measure a distance of $3\frac{13}{16}$ inches. It would take too long to count off 13 divisions, so you use another method. You know that there are 4 sixteenths in each quarter, so you count off 3 one-quarter divisions and add 1 of the sixteenth divisions. When you deal with smaller divisions, use the same method.

Frequently it is more convenient to subtract than to add a division. For example, suppose you want to lay off a distance of $\frac{63}{64}$ inch. You know that a full inch contains $\frac{64}{64}$; therefore the division you want will be $\frac{1}{64}$ inside any full inch. Look at the edge divided into sixty-fourths, count back one division within any inch, and there is the desired dimension. There is no rule to be learned; after a little practice you add or subtract (whichever is easier) without giving any conscious thought to the selection of method. Most beginners have more trouble remembering how many of the smaller divisions there are in the larger divisions than in reading the scale. If you must stop to think how many sixty-fourths or thirty-seconds there are in a given part of an inch, it will direct your mind away from the reading of the scale. Time spent in memorizing the number of smaller divisions contained in the larger divisions will greatly shorten the time required to use the steel scale and other rules.

Care of the steel scale. The expert machinist or toolmaker gives his measuring tools the same care that the infantryman gives to his rifle. He knows that the accuracy of his work will suffer from the least impairment of the tools upon which this accuracy depends.

Don't use the end of a scale to scrape foreign material off a surface. Don't beat a tattoo with it while you are reading the drawing. In short, never use it for anything except for measuring. When you put it away, wipe it with an oily cloth and *lay it down* — don't *throw* it into the drawer. Good habits formed in the early use of tools can make the difference between an expert mechanic and one who is only fair.

Linear measurements requiring a higher order of accuracy. Long before modern measuring devices were invented, machines such as the intricate clocks we see in museums were built. The method used in building these machines was to make the basic parts by eye measurement and then fit the other parts to them and to each other by feel or touch. Great accuracy was achieved in this way.

Modern practice employs this same method of touch or feel to achieve accuracy. It is employed, however, in a different way. Instead of fitting two parts of unknown dimensions to each other, a part of unknown dimension is fitted to a device of known dimension called a *gage*. In this way, if the fit is accurate, it shows that the dimension is also accurate. The gage may be of one fixed dimension or it may be adjustable, as in the case of the micrometer and vernier calipers. The construction and use of these tools will be discussed later.

In connection with gages, devices such as parallel bars, buttons, and accurately sized blocks are used. The use of these with the gages permits a high degree of accuracy in linear measurement. In each instance, the setting of the gage is dependent upon touch, and the reading done from a scale which accurately indicates the distance included between the surfaces in contact with the gage.

Straightedge surface testing. A surface may be tested by laying a *straightedge* upon it and noting whether light passes between the straightedge and the surface. (See Fig. 3–6.) Thin strips of known thickness may be passed between the straightedge and the surface being tested at points where light shows through. In this way the amount that the spot is low may be determined. By applying the straightedge at different angles, the entire surface may be tested.

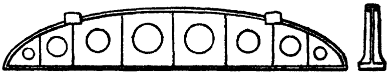


FIG. 3–6. Cast-iron straightedge.

A more accurate way to test a surface is to use the *surface plate.* (See Fig. 3–7.) These plates are generally made of specially aged cast iron, ground or scraped until they are as flat as skill and care can make them. In use they are coated thinly with a paint such as Prussian blue. The surface to be tested is rubbed very gently over the paint. The high spots are indicated by the fact that they are coated by the paint.

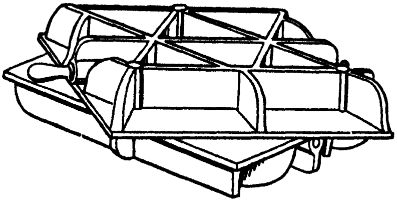


FIG. 3–7. Cast-iron surface plate.

Both straightedge and surface plate must be given very careful treatment. It is customary to keep a straightedge clamped to a board to protect its edge. Surface plates are generally kept in a wooden container. After use they are carefully wiped off, coated with a film of neutral oil, and covered.

3. USE OF RULES FOR LINEAR MEASURE

The metric steel rule. Linear measurements in the metric system are based on the meter as a unit. A metric steel rule comparable to the 6-inch scale we have discussed would be a 15-centimeter scale. If you were to lay it beside a 6-inch scale you would find it a little less than one-tenth of an inch shorter. Instead of being divided into 6 parts, it would be divided into 15 equal parts. Each of these parts is called a *centimeter,* and contains 10 *millimeters.*

These millimeters are marked off and divide each centimeter into 10 equal parts. Since each smaller unit in the metric system is equal to one-tenth of the next larger unit, it would seem logical to mark off these millimeter divisions also into 10 equal parts. We do not do this for the simple reason that the human eye could not follow the very narrow divisions that would result. Instead, each millimeter division is marked off into 2 parts, each one-half a millimeter long. A half of a millimeter is just a little longer than a sixty-fourth of an inch. When it is necessary to work with smaller units than this, the steel scale ceases to be useful and other means are employed.

Using the metric scale. Some older mechanics and draftsmen recall the days when measuring devices calibrated in the metric system were difficult to get. Even when they could be obtained it was difficult to get mechanics to use them. If an order was received to build a machine or part from metric specifications, it was necessary to convert all dimensions to the nearest equivalent in the English system. Now metric measuring tools are as available as those calibrated in English measure. When a part is to be made from a drawing dimensioned in the metric system, the mechanic works directly from the measurements given, using the metric measuring tools.

When you look at a drawing dimensioned in the metric system you find no units of measurement indicated. All numbers are understood to mean millimeters. The number 470 appearing alone would mean 470 millimeters. Since there are 10 millimeters in each centimeter, you read this 470 as 47 centimeters on your scale. If the dimension were 475, you would add 5 millimeters to your measurement by counting off 5 more divisions to the right of the 47 on the scale.

The Ford decimal scale. In 1932 the Ford Motor Company adopted a system of dimensioning in which the inch is divided decimally. The scale used for working from these dimensions has its inches divided into 10 parts. Each of these parts is divided into 5 divisions. These smallest divisions are then equal to one-fiftieth of an inch.

Dimensions for use with this scale are always given in the decimal form. Thus, five and one-half inches would be written 5.5, not $5\frac{1}{2}''$. If closer dimensioning were necessary, another digit would be added to the right; for example, the dimension 5.52 might be used. This second digit to the right of the decimal is never an odd number. It may be 2, 4, 6, or 8, but never 3, 5, or 7. The use of the odd numbers would require reading to one-hundredth of an inch. This would be expecting a little too much of our eyes. By using only numbers divisible by 2 for the second digit to the right of the decimal, we are able to use our finest divisions (one-fiftieth of an inch long) directly. For example, if we were to lay off a length of 3.54 inches, we would find our length to be 5 one-tenth divisions and 2 one-fiftieth divisions to the right of the 3-inch mark.

Emergency measurements. There are, of course, times when measurements must be made without the use of rules. These measurements can only be approximate, but sometimes they are sufficient and in most cases they are better than no measurement at all. Probably you have at some time paced off a distance, knowing that your shoe is so many inches under or over 12 inches, or one foot, in length. Possibly you know about how long a stride to take to measure off one yard; if you are tall, it may be rather a short step for you, but if you are short it may be rather a long one. These two methods of approximate measurement can be very useful. Practice them until you are reasonably accurate in them. Try also measuring the width and length of your hand, the distance from fingertips to elbow and shoulder. These measurements can be useful too.

Another means of estimating distances is to recognize the height of familiar objects. Chairs, for example, are generally about 18" high, and tables 30″ to 32″. You know your own height, and that the average man is a few inches shorter than 6′ tall. Learn also the dimensions of objects you habitually carry, such as cards, comb, and wallet. An ordinary index card, 3″ × 5″, for example, can be a useful and reasonably accurate measuring gage.

B. THE WIRE GAGE AND OTHER METAL GAGES

1. THE AMERICAN STANDARD AND BROWN AND SHARPE GAGES FOR COPPER WIRE

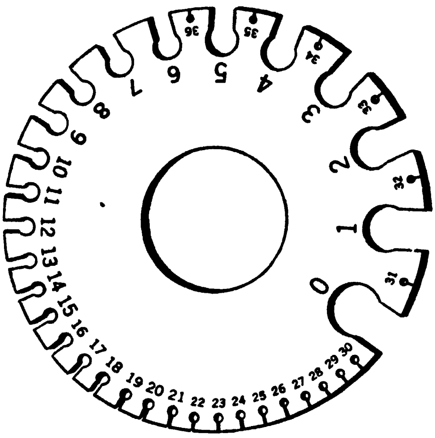


FIG. 3–8. American Standard wire gage.

The American Standard gage is used to measure copper wire. It is a disc with various sizes of holes cut around its edge. (See Fig. 3–8.) The holes are calibrated for wires from No. 0000 to No. 36; No. 0000 corresponds to .3065 of an inch, and No. 36 corresponds to .0090 of an inch. These numbers correspond to those of the Brown and Sharpe gage for copper wire. (See Table 2, Appendix A.)

2. THE BIRMINGHAM AND THE STUBBS GAGES FOR IRON WIRE

The English standard gage is the Birmingham or Stubbs gage. It is also used widely in the United States. The Birmingham gage resembles the American Standard Wire Gage. It is generally used for the measurement of iron wire, although it is sometimes used as a sheet-copper gage. The numbers on this gage range from 6 to 36.

3. USE OF WIRE GAGES

To gage a wire, insert it in one hole of the proper gage after another until you find the hole it just fits in. The number of that hole gives you the gage number of the wire.

Efforts are now being made to reduce the number of standards used in wire gages. In the meantime, many engineers in designing machinery ignore the gage numbers and specify all wire diameters in decimals of an inch. To meet the condition, circular gages are made with the number or letter size marked on one side of the gage and the decimal equivalent marked on the other. A further complication enters when parts must be matched with dimensions given in the metric system. This requires calculation of each dimension or the use of the metric conversion table.

4. THE V-GAGE

Figure 3–9 shows a gage with a V-opening. This type of gage may be obtained calibrated in gage numbers, decimals, and various combinations of units. In use, the wire, screw, or rod being measured is allowed to rest lightly in the groove and the gage marking at the point of contact indicates its size. In using any of these gages, it is obvious that the accuracy of the reading is dependent upon how closely the part measured fits the gage.

Of course, if the part measured is forced in, the reading has no meaning and the

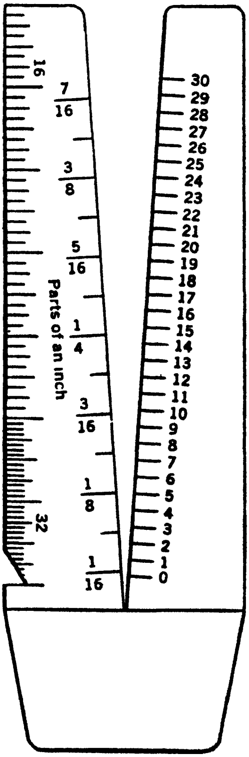


FIG. 3–9. Gage with a V-opening.

gage itself may be damaged. On the other hand, if the fit is too loose, the reading on the gage will not indicate the true measurement. With practice, a delicate sense of touch is developed which tells the user of a gage when the fit is correct. Ability to measure accurately and quickly will increase as the beginner develops this touch.

Manufacturers take great pains to make gages accurately. The surfaces of the gages are hardened to preserve this accuracy. In use, they must be protected from acid fumes and from moisture. After using they should be wiped with an oily cloth and returned to a protective container. Like other measuring tools, they should never be used for any purpose other than measuring.

If a gage is accidentally damaged in a way to affect its accuracy, it should be destroyed or, if the cost justifies it, it may be returned to the manufacturer for recalibration. If it is left available, its use while damaged may lead to errors costly in waste of material and time.

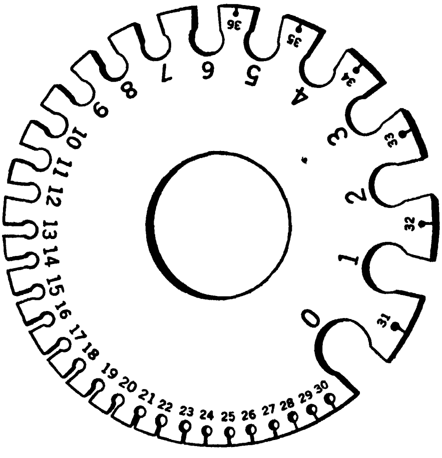


FIG. 3–10. U. S. standard gage for sheet and plate iron and steel.

5. THE SHEET-METAL GAGE

A circular gage, similar to the wire gage shown in Figure 3–8, is used for sheet and plate iron and steel. It is illustrated in Figure 3–10. It is used in exactly the same manner as the circular wire gage, and differs from it only in the relation of the gage openings to the gage numbers.

C. MICROMETER CALIPERS

1. THE DECIMAL SYSTEM

Sometimes a machinist must use dimensions closer than a sixty-fourth of an inch ($\frac{1}{64}''$), but he would encounter difficulties if this fraction were divided further. Half of $\frac{1}{64}''$ is $\frac{1}{128}''$; a quarter is $\frac{1}{256}''$. Combining fractions like these would not only consume time but would lead to many errors. All this can be avoided simply by dividing the inch into multiples of ten, as is done according to the Ford Decimal System.

As you know from your arithmetic, you can divide a number by ten or multiply it by ten simply by moving the decimal point to the left or the right. So, if you want to know the length of one-tenth of $\frac{1}{16}''$ you can rewrite it as .0625" and then, by moving the decimal point one place to the left, find the answer to be .00625". Moving the decimal one point to the right would have multiplied the dimension by ten, giving .625" as the product.

Adding and subtracting decimals is almost as easy. When two or more decimals are added, the only precaution to observe is to add together only integers which are the same number of places to the right or left of the decimal point. From the drawing a machinist sometimes learns that a part may be made a certain amount larger or smaller than a given dimension. This leeway is called *tolerance* and is indicated on the drawing in thousandths or ten thousandths. If the diameter of a shaft is indicated as $\frac{1.5005}{1.4995}$ the shaft must be not more than .0005 larger or smaller than an inch and a half.

The machinist determines the amount of leeway or tolerance by subtracting the dimension below the line from the one over it. A hole diameter might be given as $2.1600 + \frac{0.0009}{0.0005}$. The machinist would add 0.0009 to 2.1600 and get 2.1609 as the maximum size of the hole. Adding 0.0005 instead of the larger decimal, he would have the minimum size.

To convert a common fraction into a decimal requires only a simple process in arithmetic but it takes time. To save the time and avoid possible errors, a machinist can use a decimal equivalent table, such as Table 3, Appendix A. Such tables list common fractions with their corresponding values expressed in decimals.

In studying the circular gage, we found that by depending on touch we could achieve accuracy far beyond that which depended on our ability to read graduations on a scale. In using the circular gage we fitted a part of unknown dimension to an opening. If the part fitted this opening, its diameter or thickness was the measurement corresponding to the opening. If we could adjust this opening and have some way of accurately indicating what the opening was, we could apply the principle of touch measuring to an unlimited variation of measurements.

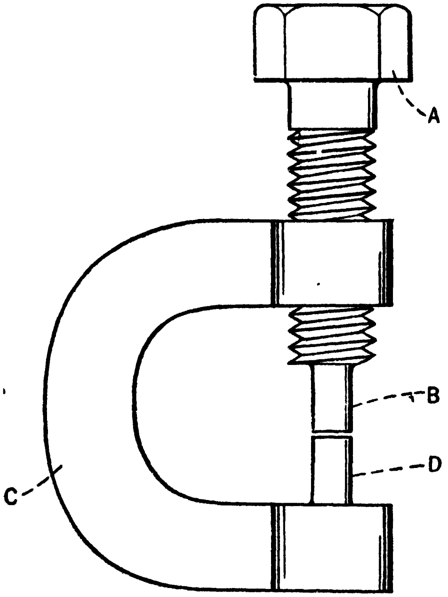


FIG. 3–11. A clamp which demonstrates the principle of the micrometer caliper.

The micrometer caliper is a tool invented to achieve this purpose. The basic principle upon which it is based is the fact that a screw will advance a fixed distance when it is rotated in a nut which has been threaded to fit it. Thus, in the clamplike device shown in Figure 3–11, the screw *A* fits a hole threaded in the frame *C*. The screw has been turned to the right until its end is in contact with the stop, or anvil, *D*. If the screw is turned to the left, its end will move from the anvil *D* by an amount determined by its *pitch,* or number of threads per inch. If the screw and hole were threaded ten threads to the inch, then one full revolution to the left would cause the distance between the end of the screw and the anvil to be one-tenth of an inch. If turned two revolutions, the opening would become two-tenths, and so on. If accurately made, the device could be used to measure thicknesses by tenths of an inch. We could improve it by making marks on the side of the screw, dividing its circumference into ten equal parts. Then, if we turned the screw one-tenth of a revolution, the opening would be increased or decreased by one-tenth of a tenth or one one-hundredth of an inch. To fit a rod .23 inch in diameter, we would turn the screw two and three-tenths revolutions to the left. With this simple device we can measure thicknesses and diameters by one-hundredths of an inch.

2. PRINCIPLES OF THE MICROMETER CALIPER

Figure 3–12 shows a skeleton view of a modern micrometer. This micrometer has many features which are lacking in the simple measuring device just described, but it employs the same basic principles in its operation.

The screw *A* in our simple device has become the spindle *C.* Both have a frame and both have an anvil. The spindle, like the screw, is threaded; but with this important difference: it is threaded with forty threads per inch. This means that when it is rotated one revolution the gap between its end and the anvil is increased or decreased by one-fortieth of an inch. One-fortieth of an inch is expressed in decimals as .025, which is 25 one-thousandths of an inch.

In the micrometer the sleeve *D* is fastened to the spindle *C.* When the spindle turns, the sleeve turns with it. The circumference of the sleeve has been divided into 25 equal parts, as shown at *Y.* When the sleeve is turned the distance included in one of these divisions, the threaded spindle rotates one twenty-fifth

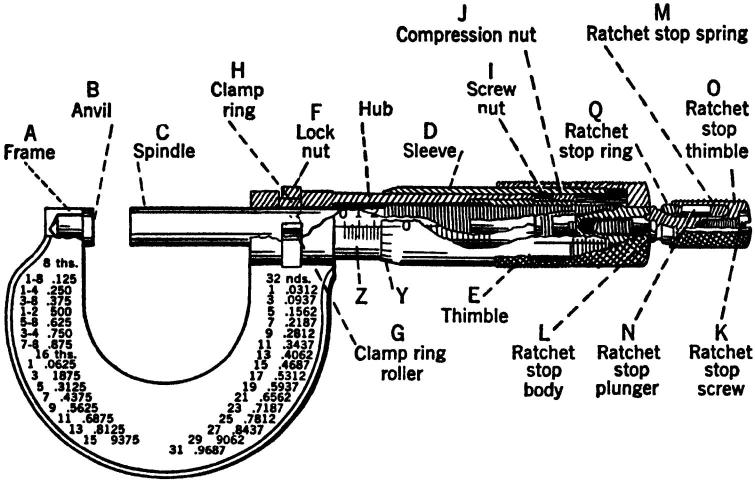


FIG. 3–12. Skeleton view of a modern micrometer.

of a revolution; the gap between the end of the spindle is increased or decreased by one one-thousandth of an inch. The divisions are numbered, and as the sleeve is turned the numbers indicate the linear advance of the spindle in thousandths of an inch. The hub of the micrometer has a scale *Z* on it with divisions .025 of an inch apart.

When the sleeve rotates one full revolution, its edge moves away from the anvil a distance equal to one of these divisions. When the end of the spindle rests on the anvil, all the divisions in the scale *Z* are covered by the sleeve *D*. Starting from this setting, if the sleeve is rotated two revolutions, two divisions on the scale *Z* will be uncovered and the space between the end of the spindle and the anvil will be 2 × .025 thousandths or .050 of an inch. If the sleeve is now rotated a twenty-fifth of a revolution — that is, through one of the divisions on the scale *Y* — the distance will become .051 of an inch. (See Fig. 3–13.)

Figure 3–14 shows a random setting of a micrometer. The sleeve has uncovered the 1 on the scale. Included between the 0 and the 1 are four divisions. Each division represents one revolution of the spindle, or .025 inch. Four revolutions mean 4 × .025, or .100. Two more divisions are exposed beyond the 1, so .050″ is added. The sum now is .150. The scale on the sleeve shows that in addition to the six revolutions indicated on the hubscale, the spindle has rotated 4 twenty-fifths of a revolution. When this is added to the .150, the reading becomes .154″.

Refinements incorporated by the manufacturer increase the usefulness and wearing qualities of the micrometer An important refinement is the ratchet stop attached to the top of the sleeve. In closing the micrometer against the object measured, the spindle may be rotated by applying the turning force to the thimble *E* on the sleeve or by turning the ratchet stop. When the spindle is turned by the thimble, a slight variation in measurement may occur because the fingers may apply more force at one time than another. Toolmakers refer to this variation as *light* and *heavy touch* or *feel*. When the ratchet stop is used, the amount of torque applied is determined by the tension to which the stop has been set. Thus, if several users of the same micrometer used the ratchet stop, they would all get the same reading.

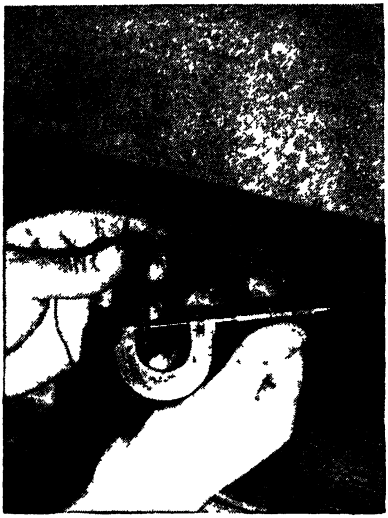
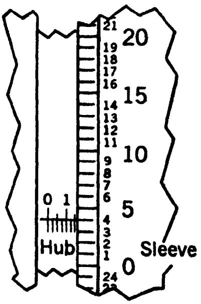


FIG. 3–13. Measuring with a micrometer.



Reading to .154

FIG. 3–14. Random setting of a micrometer.

Another useful refinement is the lock nut. By its use the spindle can be locked at a given setting. The micrometer can then be used as a snap gage; that is, the spindle can be locked in position when the same dimension is to be checked a number of times. It is important when this lock nut is used to remember to loosen it before attempting to turn the spindle.

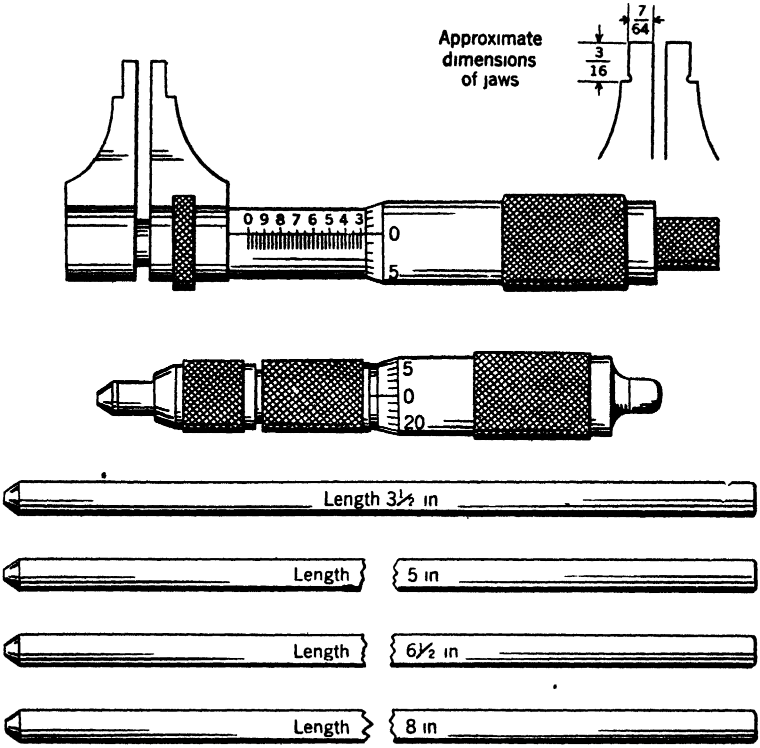


FIG. 3–15. Internal micrometers.

The internal micrometer. Sometimes it is necessary to make an internal measurement. The *internal micrometer* is used for this. Two forms are shown in Figure 3–15. In one form, accurately calibrated rods are used to increase the range. The reading of the micrometer head is added to the measurement marked on the rod.

By dividing the circumference of the sleeve into twenty-five equal divisions, we are able to read to one twenty-fifth of an inch. If each of the twenty-five divisions were divided into ten equal parts, then each of these very small divisions would represent a measurement of one ten-thousandth of an inch. These divisions, however, would be so small that we could not read a measurement without the aid of a powerful magnifying glass. To overcome this difficulty, the *vernier* principle is employed.

3. THE VERNIER SCALE

Figure 3–16 shows a micrometer setting of .1546″. We may read a micrometer equipped with a vernier scale by taking the following steps. First, take the reading to thousandths, which in this case would be .154. Then look at the scale on the hub and at the same time look at the scale on the thimble. At one point a line marked on the hub appears as a continuation of a line marking one of the divisions on the sleeve. The line on the hub which coincides with the line on the sleeve in this case is the line marked 6. Attach this 6 to the .154 and the reading becomes .1546. With a little practice the eye automatically selects the coinciding line; the corresponding number and a dimension in ten-thousandths is read as quickly as one involving thousandths.

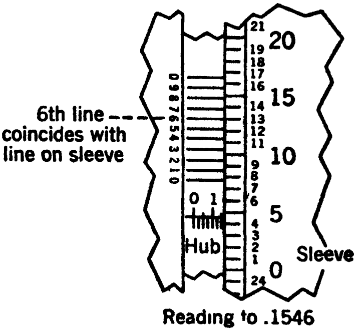


FIG. 3–16. Micrometer setting of .1546.

The principle involved may be grasped by studying Figure 3–17. In this figure the scale *A* is movable and can be slid along the edge of a fixed part *B*. Readings in thousandths of an inch are taken from the arrow *C*, which is engraved on the fixed surface. In the setting of Figure 3–17, the reading is .008 because the graduation marked 8 is over the arrow. Attached to the fixed

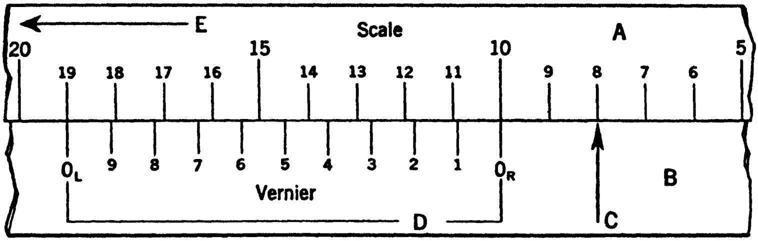


FIG. 3-17. Vernier scale.

surface upon which the arrow *C* is engraved is a vernier scale, *D*. At the setting shown, the vernier extends from the division 10 on the movable scale to the division marked 19 on this scale. Its length is equal to 9 of the divisions on the fixed scale. It is divided into 10 equal parts. Each part, then, must be equal in length to .9 of one of the parts on the fixed scale.

With the scale set as it is in the figure, the distance between the zero and the 9 on the vernier scale is $\frac{9}{10}$ as long as the distance between the 19 and the 18 on the movable scale. The distance between the line marked 9 on the vernier and the line marked 18 on the movable scale must then be equal to one-tenth of a division on the movable scale. If the movable scale is moved in the direction indicated by the arrow *E* until the line on it marked 18 coincides with the line 9 on the vernier scale, it will have been moved one-tenth of a division. Since one division on the scale represents 1 one-thousandth, then one-tenth must represent 1 ten-thousandth of an inch and the new reading is .0079. Following the same reasoning, if the scale is moved farther until the line marked 17 on the scale coincides with the line marked 8 on the vernier, the distance moved will represent 2 ten-thousandths and the new reading will be .0078. So we can proceed through each number until the zeros on the vernier coincide with lines on the movable scale; and the reading then will be .007 of an inch. Note that we disregard the numbers marked on the graduations on the movable scale. The only number we read is the number of the line on the vernier which coincides with a line on the scale.

A ten-thousandth of an inch is a very small dimension. If a piece of steel rod were measured for length to an accuracy of 1 ten-thousandth of an inch, it would be found to vary as temperature changed. The micrometer itself is made of metal and its readings are influenced by temperature. It is customary to maintain an even temperature of about 70° F. in shops where work requiring great accuracy of measurement is done. When using a micrometer to measure to ten-thousandths, it is held lightly and measurements are taken quickly to minimize the effects of heat from the hand. The micrometer used for these fine measurements should be confined to this use. Coarser measurements should be made with other instruments. In spite of every precaution, the reading of a micrometer to ten-thousandths cannot be taken as absolute. When a reading is taken under the best conditions, it is assumed to be correct within 1 ten-thousandth, plus or minus. For example, a reading of .0075″ is taken to mean that the part measured is larger than .0074″ and smaller than .0076″.

One of the precautions taken to insure accuracy in the use of precision measuring instruments is to check their measurements frequently against standards of known dimension. These standards may be hardened discs, blocks, or rods, made with extreme accuracy to a given dimension. In use, the standard and the micrometer are brought to standard temperature, and the standard measured. The extent to which the reading on the micrometer agrees with the dimension marked on the standard determines the accuracy of the micrometer.

4. VERNIER CALIPERS

The vernier principle has long been applied to a measuring tool to which it gave its name, the vernier calipers. Figure 3–18 illustrates this tool. It is used for accurate measuring, much as a micrometer is used. The fact that the head of the vernier calipers can be moved along the bar makes its range of measurement much greater than that of a micrometer.

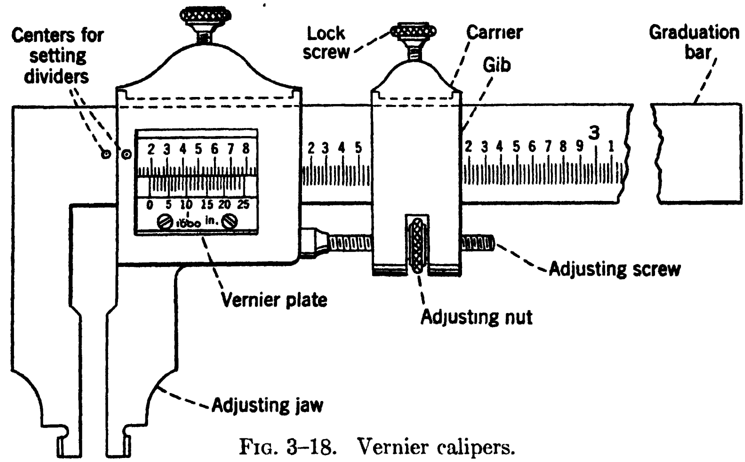


FIG. 3-18. Vernier calipers.

While the vernier principle is, of course, the same whether used on the micrometer or on the vernier caliper, there is a difference in application. On the micrometer, the vernier remains stationary and the scale is moved. On the vernier caliper, the scale is fixed and the vernier plate, attached to the adjustable jaw, moves with it.

This vernier plate has 25 graduations on it. The sum of the length of these 25 graduations is equal to the sum of 24 graduations on the bar. Each of the divisions on the bar is .025 inch long because the inch has been divided into forty parts. Just as the vernier on the micrometer indicated tenths of divisions, this vernier indicates twenty-fifths of a division. A twenty-fifth of .025 is 1 one-thousandth, so we read thousandths on the vernier scale. These thousandths are added to the reading on the bar. A vernier setting which indicates 1.436″ is obtained by noting the exposed figure 1. The line over the *O* on the vernier is one division past the 4, so we mark down the 4, and the reading is then 1.4. To this we add the one division which is equal to .025 and so obtain 1.425. To this is added the number of the line on the vernier which coincides with a line on the scale. This number is 11; that is, .011. Adding this to the 1.425 we get 1.436″.

SUMMARY

1. To make anything we need to know its form, size, and component parts. A drawing in detail, usually a blueprint, shows the size and location of everything represented. In making the part, the workman is guided by the dimensions indicated in the drawing.

2. In Europe scales are marked in centimeters, but in the United States and other English-speaking countries, the inch is still the most common unit of measure. With the use of scales it is possible to measure units smaller than the eye can see.

3. Measuring used to be done by eye and touch and often great accuracy was achieved in making intricate machines, such as clocks. The method of touch is still helpful and necessary in making fine measurements, but nowadays gages are also used. The gage, or device of known dimension, may be fitted to the part of unknown dimension to learn its correct size. A gage may be either fixed or adjustable.

4. Some kinds of gages give other kinds of measurements besides linear. A disc-shaped gage with various-sized holes through it measures the thickness of wire. A micrometer caliper, which has an adjustable opening, may also be used when measuring very small thicknesses.

5. With the use of an extra adjustment known as a vernier a micrometer can be used to give readings to small fractions of an inch. With the vernier caliper, still finer readings can be made. Because of temperature changes, which affect the micrometer itself and the metal measured, absolute accuracy for all conditions is impossible. In shops where fine measuring is done the temperature is kept even, and measurements can be made to within a ten-thousandth of an inch, but may still be plus or minus.

How many of the following terms can you define or explain?

Dimensioning
Micrometer
Straightedge
Surface plate
Wire gage
Internal micrometer
Threaded spindle
Ford decimal scale
Linear measure
Calibrated
American Standard gage
Millimeter

SELF-TESTING EXERCISES

ANSWER THESE QUESTIONS

On a separate sheet of paper numbered from 1 to 4 write the letters for the phrases that answer the following questions correctly.

1. Of what substance is a surface plate made? (*a*) Window glass; (*b*) specially aged cast iron; (*c*) polished wood; (*d*) steel.

2. By what method or methods is the thickness of wire measured? (*a*) By inserting it in holes of various sizes in the gage; (*b*) by measuring its circumference by a tape measure and calculating the diameter; (*c*) by fitting it in a groove of a gage with a V-opening and taking the reading at the point of closest fit; (*d*) by the micrometer caliper.

3. What is the length of a millimeter on the metric scale? (*a*) $\frac{1}{100}$ of a centimeter; (*b*) $\frac{1}{1000}$ of a centimeter; (*c*) $\frac{1}{600}$ of an inch; (*d*) $\frac{1}{10}$ of a centimeter.

4. What part do you read on a micrometer equipped with a vernier? (*a*) The graduations on the movable scale; (*b*) the number of a line on the vernier which coincides with a line on the scale; (*c*) the line which coincides with the line 10 on the movable scale when the zeros on the vernier meet the lines on the movable scale.

COMPLETE THESE STATEMENTS

On a separate sheet of paper numbered from 1 to 11 write the words needed to fill correctly the blank spaces in the following sentences.

A frequently used scale measures an inch into (1) and ..(2) on the edges of one side, and into (3) . and (4) on the edges of the other side. A ..(5) , or device of known dimension, may be used to determine the size of a part of unknown dimension. A 15-centimeter scale is approximately ..(6) . inches long. When a reading is taken with a vernier caliper under the best conditions it is assumed to be accurate to within . (7)... The position of a vernier used with a micrometer scale is ..(8).., the micrometer scale being movable. On the vernier caliper the scale is fixed, and the vernier plate ..(9) . with the adjustable jaw. The number of graduations marked on a vernier plate is ..(10)... On a metric scale the only numbers which appear refer to ..(11)...

beginner because they are not descriptive of relative hardness. Basswood, poplar, aspen, and cottonwood are deciduous trees, shedding their leaves in the fall; therefore they come under the general grouping of hardwood. But actually they are among the softest of woods. On the other hand, longleaf pine is as hard as the average hardwood; but since it is of the evergreen or conifer group it is known as softwood. While it would be better to use the proper botanical names *gymnosperm* and *angiosperm*, or the simpler terms *conifer* and *deciduous*, the terms *softwood* and *hardwood* have been in use for so many years that they have become part of the woodworker's vocabulary.

Cells of a tree. All trees are made up of cells. The size or arrangement of the various cells is one of the best means of distinguishing one class from another and also of distinguishing different woods of the same class. Woods such as ash, basswood, oak, poplar, maple, and walnut are all hardwoods. Pines, spruces, and firs are softwoods. Characteristics of cell structure common to the hardwoods are different from those common to softwoods. The arrangement of hardwood cells is shown in Figure 4-2 and of softwood cells in Figure 4-3.

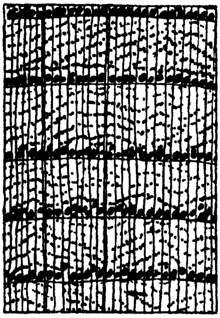


FIG. 4-2. Cross section of an American elm, about twice its natural size.

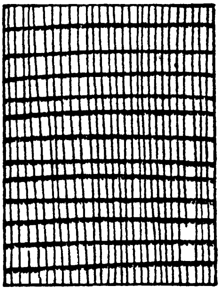


FIG. 4-3: Cross section of a spruce, about twice its natural size.

Annual rings. As the tree grows the cells increase in number, adding more wood to the cross section or diameter (as well as to the height) of the tree. This growth from season to season produces what are known as *annual rings.* They can be seen at the end of a piece of wood or on the end of a log, where they appear as concentric circles. (See Fig. 4–1.) It takes one year to produce a ring; therefore, by counting the number of rings at the end of the log, the age of the tree from which the log was cut can be determined.

These so-called rings are not lines, but small cells and fibers produced during the summer when the growth of the tree slackens. The greatest growth of the tree during any one season takes place in the spring. At this time the cells and fibers grow to a relatively large size. As the season progresses the speed of the growth slackens, with the result that the size of the cells is reduced. It is this difference in size between the large spring cells and the small summer cells that produces the "lines" that form the annual rings. Annual rings are also visible on the face and edge of a piece of wood. On these surfaces they appear as straight or curved lines as shown in Figure 4–4.

Medullary rays. Both hardwoods and softwoods have horizontal fibers that extend across the vertical fibers; these are known as medullary rays. The medullary rays radiate from the center of the tree and appear as radial lines. (See Fig. 4–1.) Their function is to store the food material of the tree and to distribute it horizontally. When a log is sawed so as to expose the medullary rays, this surface is commonly called *edge grain* when applied to softwoods and *quartersawed* when it refers to hardwoods. In some hardwoods the surface produced by quartersawing is covered with large "flakes" formed by the medullary rays leaving and entering the surface. This is most notable in quartersawed oak and is valued in the manufacture of furniture because of its attractive pattern.

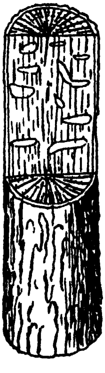


Fig. 4–4. White oak cut to show the grain.

Heartwood and sapwood. As the tree grows and increases in diameter, the cells at the center no longer conduct sap through the tree. In this change, the living cells die; they become infiltrated with various substances, some of which darken the wood. With some species these infiltrations are known to add appreciably to the weight of the wood. The portion of the tree that undergoes this change is known as *heartwood.*

The light-colored sapwood is next to the heartwood. (See Fig. 4–1.) It contains the living cells and fibers that function as conductors of food and water from the roots to the leaves. In its green state, sapwood contains more moisture than heartwood; its weight per cubic foot is therefore higher. But when the wood is seasoned this moisture is removed from the sapwood, bringing the weight of the sapwood down to that of the heartwood.

While it is often said that heartwood is stronger than sapwood, this is not always true. In thousands of tests made on various woods grown in the United States there has been found in most species no effect on the properties of the wood due to this change. Such trees as the redwood and the black locust have been found to produce stronger heartwood than sapwood, but these are the exception. In some respects heartwood is superior to sapwood. Heartwood is less subject to attack by stain, by mold-producing fungi, and by certain insects. Because of the dark color of some heartwood, it is considered more ornamental for some uses. Because of its light color, sapwood is used for such things as floors and furniture with a bleached finish.

Cambium. Between the sapwood and the inner bark is a layer of cellular tissue known as the *cambium.* (See Fig. 4–1.) This layer is made up of two parts; one always remains the cambium, and the other forms the new cells and fibers. It is due to the constant developing of this tissue that the tree is capable of increasing in size.

Bark. Outside the cambium layer, and covering it, is the bark. This thick outside covering of the tree is its protective coat. The bark has two parts, the inner bark or *bast,* and the outer bark or *cortex.* In some trees the bast is the thin hairy material on the inner surface of the bark; it is sometimes stripped off and used in the manufacture of rope and cloth. The cortex is also important commercially; cork, tannic acid, and certain medicines are obtained from the cortex of some trees.

2. LUMBER AND LUMBERING

The term *lumber* applies to boards, planks, timbers, and beams that have been cut from the tree. *Boards* are any pieces of wood measuring up to 1½ inches thick. Planks range in size from 1½ to 4½ inches in thickness and at least 6 inches in width. *Timbers* and *beams* are terms that are usually applied to the larger pieces of lumber prepared for building purposes. The production of lumber from the tree involves two operations: *logging* and *milling.*

Logging. Logging consists of felling the tree, cleaning the trunk of all branches, cutting the trunk or logs into standard commercial lengths, and delivering the logs to the sawmill. Standard lengths of logs range from 10 feet to 24 feet, depending on the type of wood. (They are always cut in multiples of two feet.) It is possible to obtain lumber of greater length, but the log from which such lumber is to be cut must be delivered to the sawmill on special order.

Logging is a year-round operation and the time of cutting has very little effect on the durability or other properties of the lumber, provided the logs are properly cared for after they have been cut. Logs cut in the spring and summer must be handled in a manner different from those cut in the fall and winter. Spring-cut and summer-cut logs are more likely to be attacked by insects and fungi. Opportunity for decay by attack of fungi can be reduced to a minimum if the log is stripped of its bark when it is cut, then piled openly on skids. Under no condition should a log be allowed to lie in direct contact with the ground. Another point which makes the handling of logs cut in the early part of the year different from those cut in the colder weather is seasoning, which we shall discuss in detail later.

Milling. The manner in which a log is cut into boards and planks has an important bearing on the quality of the lumber. There are two methods used: *plain sawing* and *quartersawing.*

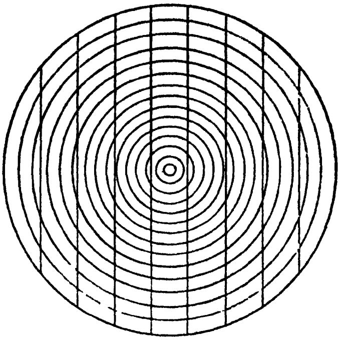


FIG. 4–5. Plain or slash sawing.

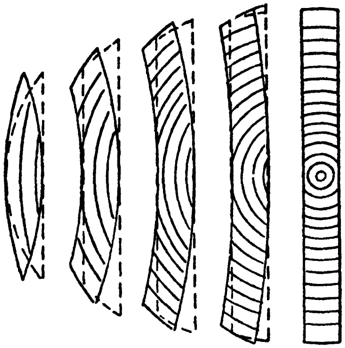


FIG. 4–6. Warping as a result of plain sawing.

Plain sawing is the more common method, and has the least amount of waste. (See Fig. 4–5.) Such terms as *flat* and *slash* are also applied to this method.

While it is possible to obtain more lumber from a plain-sawed log, the lumber obtained is not of the best quality; such boards are more subject to warping. (See Fig. 4–6.) As shown in Figures 4–5 and 4–6 the annual rings pass diagonally across the end of each board except the one at the center. In every case except this one there is visible at the end of the board an entire segment or section of the arc that forms the annual ring. As this section of the arc formed by the annual rings increases in size, the possibility of the board's warping is also increased.

Quartersawed lumber is also spoken of as being *edge sawed* or *edge grained*, especially when referring to softwood. A log that is to be quartersawed is first cut into four parts as shown in Figure 4-7*E*. From these quarter-sections the planks and boards are cut in one of the four methods discussed below. In each case the boards are cut so that the length of the annual rings at the end of each piece is as short as possible. Quartersawing will produce lumber not greatly subject to warping. This method of cutting wastes wood, and because of this waste the cost of quartersawed wood is higher.

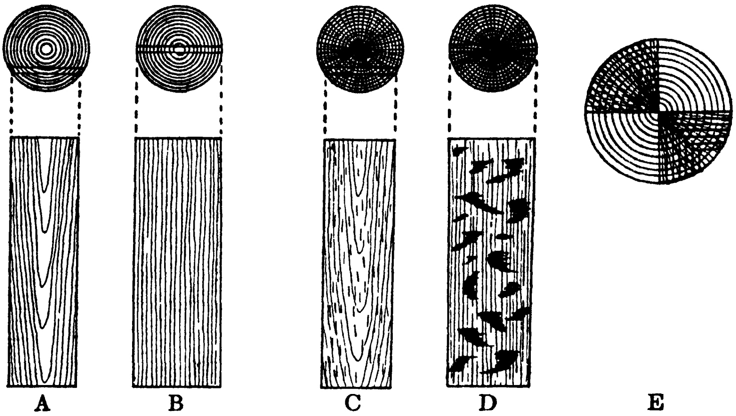


FIG. 4–7. Grain in wood. *A* and *B* show grain caused by annual rings. *A*, cut near the side of the log, reveals the *sides* of annual rings ("bastard grain"); *B*, cut through the middle, shows the *edges* of annual rings ("rift grain"). *C* and *D* show the additional grain caused by medullary rays. *C*, cut near the side, reveals cut-off *ends* of medullary rays; *D*, cut through the middle, reveals the wide *sides* of medullary rays characteristic of "quartered oak." *E* shows two ways of quartersawing

The *radial-and-tangential* method of cutting will produce a good grade of wood, attractively marked by the medullary rays and free from warp. The *tangential* and *quarter-tangential* methods of sawing will produce some pieces that are radial and others with a larger section of the annual ring. The pieces obtained by the true radial-cut method are identical to those obtained in radial sawing; but as each succeeding piece is cut and the length of the annual ring increases, the possibility of the piece's warping also increases. The best lumber is obtained when the quarter-section of the log is cut by the *radial* method.

Seasoning. After the logs have been sawed into planks, boards, and timbers they must be seasoned. Seasoning is nothing more than a drying process whereby the moisture content of the wood is reduced. Moisture occurs in wood in two forms: free water and imbibed water. Free water is found in the cells, and imbibed water is found in the porous walls of the cell. When the drying process takes place, the free water evaporates first; this stage is known as the fiber-saturation point. A piece of wood has approximately 30 per cent moisture at this point. As the drying process continues, the imbibed water is removed from the cell walls. This causes the wood to shrink.

The purpose of seasoning is to shrink these cells before the lumber is used; for if this is not done shrinkage will take place eventually, with the result that whatever has been made of the unseasoned wood will tear itself apart. The drying or seasoning of lumber is done in two ways: *air seasoning* and *kiln drying*. The use of a kiln to dry lumber reduces the moisture content far below that obtained by air seasoning.

Air seasoning. Air seasoning is the cheapest method of drying lumber, for no expensive equipment is required. It is an extremely slow method, taking from 30 to 300 days to season a piece of stock, depending on the nature of the wood and the size of the material. Table 3 in Appendix A gives the approximate drying period required for stock that is 1 inch square. The drying time for stock that is thicker is more than proportional to the increased thickness; for example, a piece of wood 2 inches thick will take more than twice the time shown in the table. The drying time shown in the table is based on the average climatic conditions of the regions in which the particular species is native. Stock piled for seasoning in the spring and summer (the best drying weather) requires a minimum period; material set out for seasoning in the fall and winter takes the maximum length of time.

Seasoning means the reducing of the water content in a piece of wood. The water must be evaporated and carried away from the lumber in the form of water vapor. This can be done only by allowing free circulation of air around each board or plank. There are several factors that must be taken into consideration when air-seasoning wood. They are the direction of the prevailing wind, variations in temperature, and variations in humidity. The wind is necessary in order to keep the air circulating about the stacked lumber. High temperatures will speed up the evaporation and low temperatures will retard it. Low humidity will hasten the drying and high humidity will slow it down. The perfect combination would be high wind, high temperature, and low humidity; but these three factors very rarely are found together.

The stacking or piling of lumber for seasoning is of the utmost importance. There are two methods of stacking lumber to allow free movement of air around each piece. In the first the lumber is piled with small spacer sticks, usually measuring 1″ × 2″, between each board. The spacers should be placed close enough so that there will be no sag in the plank or board. In the second the boards are standing *on end*, with the edge resting against a support, and piled alternately. The stacked lumber should be protected against rain, the direct rays of the sun, and dampness from the ground.

At best, this method of seasoning will bring the moisture content of the lumber down to about 20 per cent. Stock having a moisture content this high will be found satisfactory for rough work such as general construction, but for cabinetwork or patternmaking this moisture content is too high.

Kiln drying. In order to reduce the moisture content to produce a piece of wood that can be used for cabinetwork or patternmaking, it is necessary to use a forced drying method. This method is known as kiln drying. A drying kiln is nothing more than an air-conditioned oven in which the wood to be dried is placed. The main difference between the air- and kiln-drying process is that, in the kiln, heat, humidity, and circulation are controlled every minute. In most cases, lumber that is to be kiln dried is first air-seasoned, then placed in the kiln to further reduce its moisture content.

Table 3 in Appendix A gives the drying time for reducing the moisture content of air-seasoned stock from 20 per cent to 6 per cent, as well as the time required to reduce unseasoned stock to the 6 per cent content that is advisable for general cabinetwork. It should be noted that stock which is to be used for airplane construction, while having a higher moisture content than cabinet wood, takes a longer period in the kiln. The requirements for airplane stock are such that mild drying schedules must be used, and therefore a longer period of time is required.

It is possible for lumber to pick up moisture and thus for the cells to expand again after it has been taken from the kiln. Kiln-dried lumber should be stored with care so as to avoid exposing it to dampness.

Seasoning defects. Defects may develop in seasoning too rapidly or too slowly. When wood seasons too rapidly, uneven shrinkage takes place. Such defects as checks, honeycombing, warping, loosening of knots, and collapse of the cells are signs of uneven shrinkage.

Checks are lengthwise separations of the wood, usually across the annual rings.

Honeycombing is a form of checking which is not often visible on the surface of the wood, as it commonly occurs in the interior, usually following the medullary rays.

Warping may take the form of crook, bow, cup, or twist; it is a condition which distorts the board from a true surface. (See Fig. 4-8.)

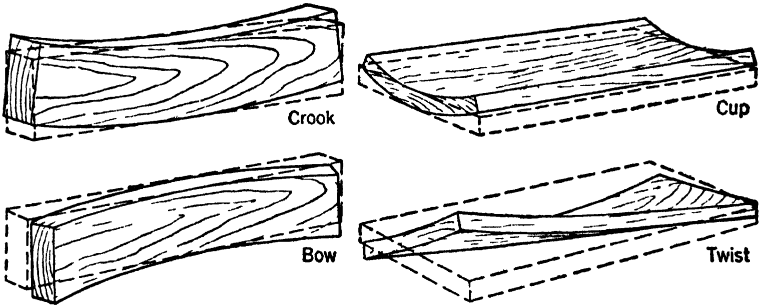


FIG. 4-8. Various types of warping.

Collapse is the flattening of a single cell or rows of cells in the heartwood, shown externally by a caved-in or corrugated appearance of the surface.

Wood that seasons too slowly may develop such defects as molds, stains, and decay, all of which can be traced to the action of fungi.

If proper air circulation is maintained during the drying process, these defects can be eliminated or kept to a minimum.

Seasoning proceeds more rapidly during the late spring and summer and may cause excessive checking. This shows up in the wood as a split or series of splits at the ends of the log. These checks may run the full length of the log. Trees cut in the late fall and winter season more slowly, with a corresponding reduction in checking. There is very little danger of insects or fungi attacking wood stored out of doors in the cold weather, for insects are dormant, and what moisture is present is in a form that is not conducive to fungus growth. By the time warm weather arrives, the wood is partly seasoned and therefore less susceptible to attack. Since fall- and winter-cut wood seasons more slowly, it is less likely to check excessively.

Selection of lumber. The selection of the proper lumber for any particular job is of prime importance to the woodworker. Each kind of wood has its own characteristics, and these must be known if a wise selection is to be made. Table 4 in Appendix A lists the majority of the trees to be found in the United States and their important characteristics and uses. The uses shown in the chart are an indication of the properties of different kinds of lumber.

Grades and sizes. Lumber grades are fairly well standardized, officially, by the American lumber standards. Many lumber retailers use a local grade classification or their own judgment; therefore when ordering lumber from the local yard be sure that the standards you have in mind correspond to those your retailer is using.

Softwoods. Softwoods, such as pine, fir, and hemlock, are graded as follows:

A Select
B Select
C Select
D Select

#1 Boards
#2 Boards
#3 Boards
#4 Boards
#5 Boards

The top grades, A Select and B Select, are suitable for natural and paint finishes. These are often sold together, and called B or Better grade. C Select and D Select are suitable for paint finishes only: The ordinary grades of lumber beyond the Select grades are based on the size, number, and location of knots, pitch pockets, and other defects. Knots and pitch pockets are strictly limited in the Select grades, and therefore have no influence on the strength of the board. #1 Boards and #2 Boards have little difference in strength, and although weaker than the Select grades they are sufficiently strong for permanent structures. #3, #4, and #5 Boards permit large knots, holes, and shakes, with a corresponding weakening of the board.

Hardwoods. The two highest grades of hardwood are known as Firsts and Seconds; they are usually sold combined. These gradings are based on factory use rather than on building requirements, and take into account the yield and size of the cuttings with one face or surface clear. Hardwood lumber that is used for building construction is graded the same as softwoods such as #1, #2, #3, #4, and #5 Boards.

Sizes. Lumber, as ordinarily stocked in the average local yard, is surfaced or dressed smooth on the two faces and the two edges. Stock may also be carried dressed on the faces only. The purpose of the dressing is to make the lumber ready for immediate use, and to avoid paying transportation charges on material that would have to be removed and discarded when the board is put to use.

Boards, when purchased at the lumberyard, are sold according to their nominal size; that is, a piece of wood that is listed by the lumber dealer as measuring $1'' \times 6''$ would actually measure $\frac{25}{32}'' \times 5\frac{1}{2}''$ if it was dressed on all four sides. If the same piece were sold rough-dry (seasoned but not dressed), it would measure $\frac{29}{32}'' \times 5\frac{5}{8}''$. When the dimensions of dressed lumber are less than those shown in Table 5 in Appendix A, the lumber is known as substandard.

Board measure. Lumber is bought and sold by a unit which is known as the *board foot.* The board foot is actually a cubic measure and means a piece of wood the contents of which is 1 foot square and 1 inch thick. It is obtained by multiplying the thickness in inches, by the width in feet, by the length in feet. The formula would be *inches* × *feet* × *feet.* A piece of wood measuring 1″ × 4″ × 10′ would contain $3\frac{1}{3}$ board feet.

$$1 \times \frac{4}{12} \times 10 = \frac{40}{12} = 3\tfrac{1}{3}$$

(*inches* × *feet* × *feet* = *board feet*)

When purchasing lumber, remember that the cost is based on the size of the rough stock, or the size of the original piece that was required to produce the piece being delivered. The purchaser must pay for the waste. Therefore when figuring the board-foot content always use the nominal size of the board or plank.

Bill of materials. When ordering lumber a *bill of materials* should be made. It should include the number of pieces required and the length, width, and thickness of each piece.

In order to obtain from the lumberyard the piece of wood you have in mind, you should have a thorough understanding of what is meant by length, width, and thickness as applied to lumber. When dealing with lumber, the *length* of a piece is the measurement taken from end to end, or with the grain; it never changes. The *width* is the measurement taken from edge to edge, or across the grain. The *thickness* is the measurement from face to face. Figure 4–9 shows these dimensions, all of which are based on their relation to the grain.

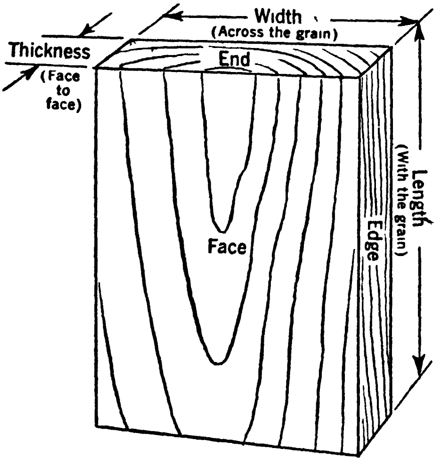


FIG. 4–9. The three dimensions of a piece of lumber.

The two *faces* of the wood are the largest surfaces produced when a log is cut parallel to the axis of the tree. The *edges* are the narrow surfaces that are parallel to the axes of the tree. They are also the two sides which are adjacent to the faces. The ends are the two surfaces cut at right angles or across the center axis of the log.

When preparing a bill of materials, there are two methods of arranging the required information, depending on whether standard-size lumber is being ordered or the lumber is to be cut to a specified size at the lumberyard or mill. A bill of material for ordering stock-size lumber would have the necessary information arranged as follows:

2/10′ 1″ × 2″

Such a bill would call for 2 pieces of lumber 1″ thick, 2″ wide, and 10′ long. The number of pieces of like size are shown by the first figure; the length of these pieces is given in the second figure, and the thickness and width of the material ordered are shown in the third and fourth figures, respectively. The figures must always be written in that order.

When ordering lumber cut and finished to special sizes, the arrangement of the figures is slightly different. In this case the number of pieces would be listed first, the thickness next, then the width and the length. For two pieces of wood ¾″ thick, 2½″ wide, and 48″ long, a bill of materials, or *cutting list* as it is often called, would appear as follows:

2 pc. ¾″ × 2½″ × 48″

Since lumber is stocked in standard dimensions at the lumberyard, to order lumber you must make up a cutting list first. The cutting list must show the thickness, width, and length of each piece needed, which you obtain from a drawing or plan of the article that is to be made. After the cutting list has been made up it is necessary to determine the required stock-size lumber.

In the list of standard-size stock will be found the various dimensions of lumber carried in the lumberyard. If two pieces of ¾″ × 2½″ × 48″ lumber are needed, they can be obtained from one piece of standard-size stock 1″ × 3″ × 10″. Although only 8′ are required, it may be necessary to obtain a piece 10′ long, as standard lumber is generally cut in multiples of two starting with 10′. Even though an 8′ piece could be obtained, it will not be enough to obtain two 48″ boards because you must allow for waste or loss in cutting.

3. HOW TO READ A DRAWING

A drawing having all the information necessary to make an object is known as a *working drawing.* The type of working drawing which the woodworker most often uses is known as an *orthographic projection.* Drawings made in this manner show all three sides of the object in a single view. (See Fig. 4–10.) The front of the object is shown on the *front view.* This view is not sufficient to give the complete form of the object, as only two dimensions can be shown: the length and the height. There is no way of indicating the third dimension, which is the width or depth of the object, on the front view. This makes it necessary to have a second view known as a *top view,* showing the width (as well as the length) of the object. It can be seen that on these two views all the necessary information as to the over-all size of the object can be given. A third view, known as a *side view,* is often necessary when the object is of such a shape that sufficient information cannot be conveyed by two views.

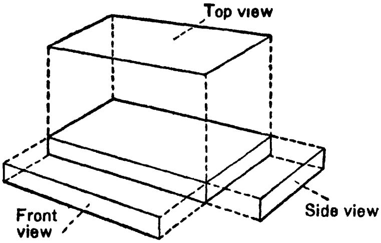


FIG. 4–10. An orthographic projection.

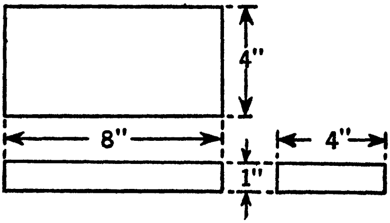


FIG. 4–11. Arrangement of front, top, and side views.

These views are arranged as shown in Figure 4–11. The front view is in the center, the top view above it, and the side view placed alongside the front view. The different views are joined together by projection lines. The length, width, and thickness of the object are given by means of a number in inches or feet placed between dimension lines. These are lines having arrowheads at each end, signifying that from point to point the dimension is as stated by the number placed between them.

A. LAYOUT AND TESTING

The fabrication of lumber requires not only the use of the tools described and shown in the previous chapters, but the knowledge of certain woodworking processes, the first of which is *squaring*. This process involves three distinct operations: (1) *layout* — laying out the stock to a rough size; (2) *cutting* — sawing the stock; and (3) *shaping*—planing all surfaces to reduce the stock to the proper size.

The rough-stock list. The bill of materials, which is the itemized list showing the thickness, width, and length of the various pieces, is used to lay out the stock. The dimensions given in the bill are the sizes to which each piece must be planed; it is, of course, necessary to start with pieces that are a little larger. A *rough-stock list* should be made from the bill of materials by adding $\frac{1}{8}$ inch to the thickness and $\frac{1}{2}$ inch to the length and width. If a bill of materials calls for a piece of wood $\frac{3}{4}''$ × $4\frac{1}{2}''$ × 12″, the rough-stock list should be made up to read $\frac{7}{8}''$ × 5″ × $12\frac{1}{2}''$

Laying out the stock. With this rough-stock list prepared, the work of laying out the stock is undertaken. The board from which the stock is to be cut should be examined for defects or damage that would make part

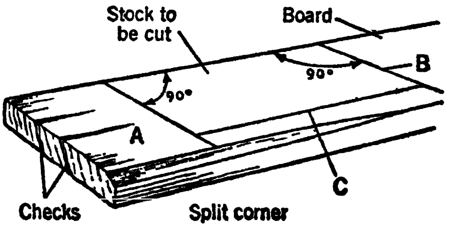


FIG. 4–12. Squaring a line across the grain.

of the stock useless. If any such defects are found, the stock will have to be laid out so that they can be removed.

When laying out the stock, the first operation is to draw a line across the grain at right angles to the edge. (See Fig. 4–12.) The trysquare is used for this. The handle of the trysquare must be placed against the edge so that the line drawn will be at right angles to the edge. The location of this first line should be beyond any checks which may be in the end of the stock, as shown in Figure 4–12. From this line *A* the required length is measured off. Line *B* is squared across the grain at this point. The width is laid out and marked by a line running with the grain, parallel to the edge. (See Fig. 4–13.)

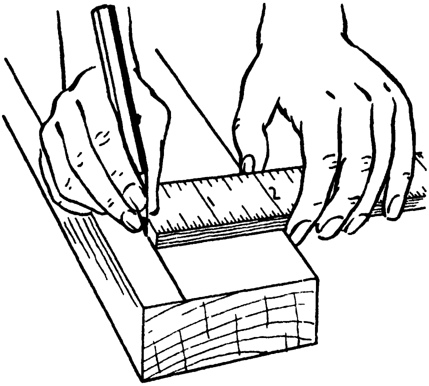


Fig. 4–13. Marking the width by a line running with the grain.

The stock is cut to its rough size by the use of a handsaw, the crosscut handsaw being used to cut *across* the grain and the rip handsaw to cut *with* the grain. The use of these tools is described and shown on pages 32–34.

1. MEASURING WITH A RULE

Proper use of the rule. The rule is a tool for measuring or reproducing measurements. Two points must be kept in mind when using it: (1) One end of the rule must be flush or even with the point from which the measurement is to be taken or made, as shown in Figure 4–14. This may be a point somewhere on the surface, as in Figure 4–14*A*, or a point at the end of the surface, as in Figure 4–14*B*.

(2) The reference mark made by a pencil or knife at the point

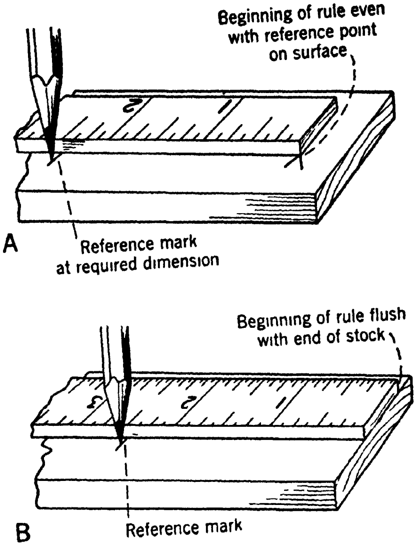

Beginning of rule even with reference point on surface
2
1
A
Reference mark at required dimension
Beginning of rule flush with end of stock
3
2
1
B
Reference mark

FIG. 4–14. Proper use of the rule.

which establishes the required measurement on the stock may be a straight line at *right angles* to the edge of the rule or may be established by means of an arrowhead, the point of which should be the exact location.

The outside dimensions of round or square stock are measured with a caliper rule.

Drawing lines with a rule. A rule and pencil can be used to gage lines parallel to an edge. Figure 4–13 shows how the rule is used for this operation. Hold the rule in one hand, with the thumbnail at the desired dimension and at the same time in contact with the edge of the board. The rule must be kept at right angles to or square with the edge. Hold a pencil point firmly against the end of the rule. Move the rule along, holding the thumbnail against the edge of the stock and the pencil against the end of the rule.

The edge of the rule may also be used for drawing straight

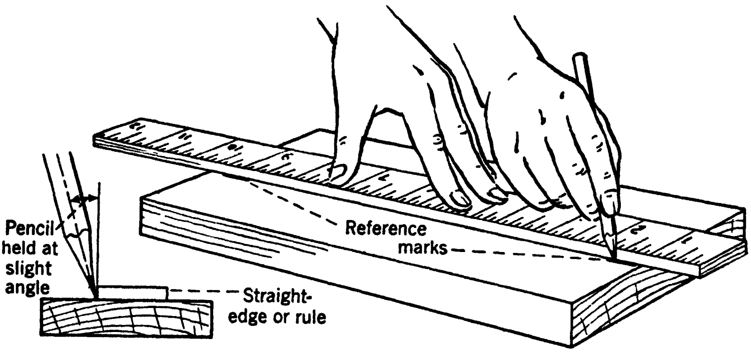


FIG. 4–15. Connecting two points with a straight line by means of reference marks.

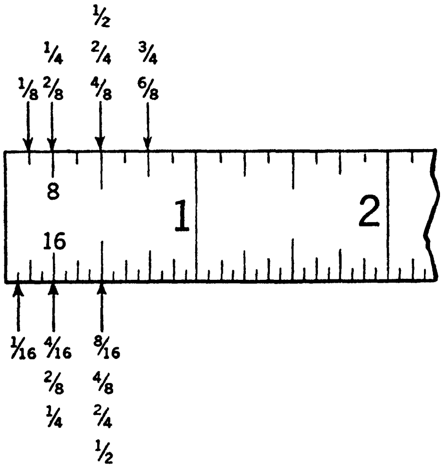


FIG. 4–16. An inch divided into 8 spaces.

lines provided the edge of the rule is true. The folding rule, zigzag rule, or the flexible steel tape should not be used for this purpose, since the accuracy of a line drawn with these tools cannot be dependable. To connect two points with a straight line, place the edge of the rule on the reference marks, as shown in Figure 4–15. These reference marks should be as far apart as possible.

Hold the rule with one hand at the center of the rule. The pencil should be held at a slight angle so that the top of the pencil will ride along the edge of the rule.

Reading a rule. The accuracy of layout work depends a great deal on the ability of the woodworker to read a rule correctly. Rules are divided into large sections, each of which measures one inch (in the English-system rules). Each of these sections is subdivided into smaller units which are fractions of the inch. When an inch is divided into 8 spaces, as shown in Figure 4–16, each space is $\frac{1}{8}''$; when an inch is divided into 16 parts, each part equals $\frac{1}{16}''$. Measuring with a rule was discussed in more detail on pages 111–114.

The table of equivalents listed below will aid in converting to 8ths or 16ths any of the common fractions that the woodworker uses.

$\frac{1}{16}$
$\frac{2}{16} = \frac{1}{8}$
$\frac{3}{16}$
$\frac{4}{16} = \frac{2}{8} = \frac{1}{4}$
$\frac{5}{16}$
$\frac{6}{16} = \frac{3}{8}$
$\frac{7}{16}$
$\frac{8}{16} = \frac{4}{8} = \frac{2}{4} = \frac{1}{2}$

$\frac{9}{16}$
$\frac{10}{16} = \frac{5}{8}$
$\frac{11}{16}$
$\frac{12}{16} = \frac{6}{8} = \frac{3}{4}$
$\frac{13}{16}$
$\frac{14}{16} = \frac{7}{8}$
$\frac{15}{16}$
$\frac{16}{16} = \frac{8}{8} = \frac{4}{4} = \frac{2}{2} = \frac{1}{1} = 1$

2. LAYOUT AND TESTING WITH TRYSQUARE

Layout. As a layout tool the trysquare is used whenever it is necessary to draw or scribe a line at right angles to any given surface. The handle of the trysquare must be kept in contact with as much of the surface as possible, for if the handle is off in space it will have insufficient bearing surface to insure a line that is square.

Checking a trysquare. The accuracy of a trysquare can be readily checked by means of lines drawn with it. Place the handle of the trysquare against the edge of a board having a true edge; that is, an edge that is straight. Draw a line across the face along the blade of the trysquare. Then turn the trysquare over and draw a second line. If the trysquare is accurate, the lines will coincide; but should the trysquare be out of square an error will show.

Laying out angles. The framing square is most commonly used in laying out angles. By using the graduations on the body and tongue of the framing square, it is possible to lay out any angle. The most common angles the woodworker uses are those required in the construction of polygons — figures or shapes having three or more equal sides. The following chart shows the various polygons, the angles at which stock must be cut to form them, and the measurements on the tongue and body of the frame square that must be used to obtain the required angle.

Polygon	Angle (degrees)	Tongue (inches)	Body (inches)
3	30	12	$20\frac{7}{8}$
4	45	12	12
5	54	12	$8\frac{25}{32}$
6	60	12	$6\frac{15}{16}$
7	$64\frac{2}{7}$	12	$5\frac{25}{32}$
8	$67\frac{1}{2}$	12	$4\frac{31}{32}$
9	70	12	$4\frac{3}{8}$
10	72	12	$3\frac{7}{8}$
11	$73\frac{7}{11}$	12	$3\frac{17}{32}$
12	75	12	$3\frac{7}{32}$
14	$77\frac{1}{8}$	12	$2\frac{3}{4}$
16	$78\frac{3}{4}$	12	$2\frac{13}{32}$
18	80	12	$2\frac{1}{8}$
20	81	12	$1\frac{19}{32}$

The framing square is used, for example, to lay out an angle of 60 degrees. The 12″ mark on the tongue is lined up with the edge of the stock while the $6\frac{15}{16}$″ dimension on the body is also brought in line with the same edge as shown. The line drawn along the body when the framing square is in this position meets the edge at an angle of 60 degrees as indicated. The laying out of any of the above angles is done in the same manner, using the measurements for the tongue and blade in the above chart to obtain the angle indicated. The angle in every case will be produced by the line drawn along the body of the square. A line which is drawn along the tongue will be the complement of the angle shown, which is the difference between 90 degrees and, in this case, 60 degrees; the difference is 30 degrees.

The use of a wood fence attached to the framing square is of considerable help when marking off a number of like angles. Such a fence is made of a strip of wood having two saw cuts large enough to permit the tongue and body of the square to be inserted. The face can be held securely in any position by means of bolts and wing nuts. (See Fig. 4–17.)

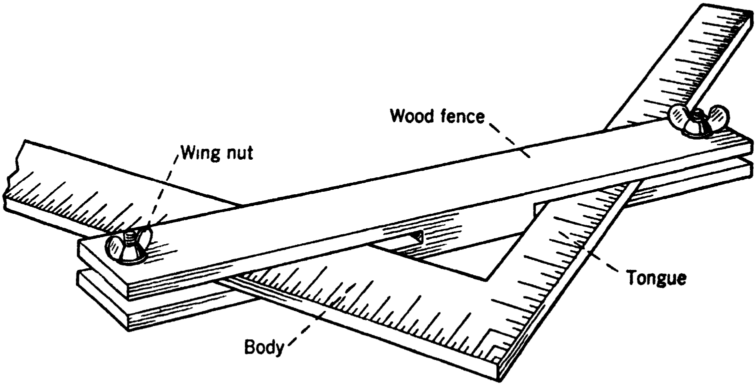


FIG. 4–17. A steel square with a wood fence.

As a layout tool, to draw lines at an angle other than 90 degrees, or exactly a right angle, to any face, edge, or end, the T-bevel is frequently used. The use of the T-bevel was discussed on pages 8–9.

3. LAYOUT, USING PATTERNS

Stock that is to be laid out in other than a geometric design requires the use of a pattern. A pattern is a full-sized outline of the shape to which the material is to be cut. It may be made of paper, cardboard, thin wood, or metal. The way in which a pattern is placed on the stock will depend on how the pattern is laid

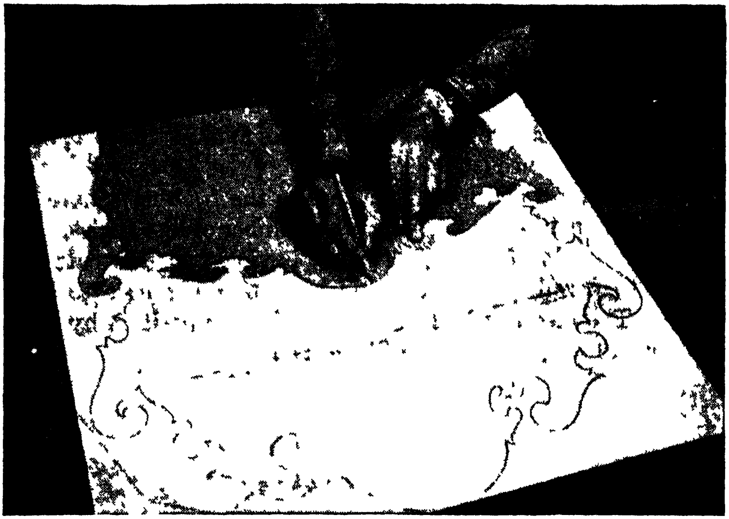


FIG. 4–18. Tracing a pattern on a piece of stock

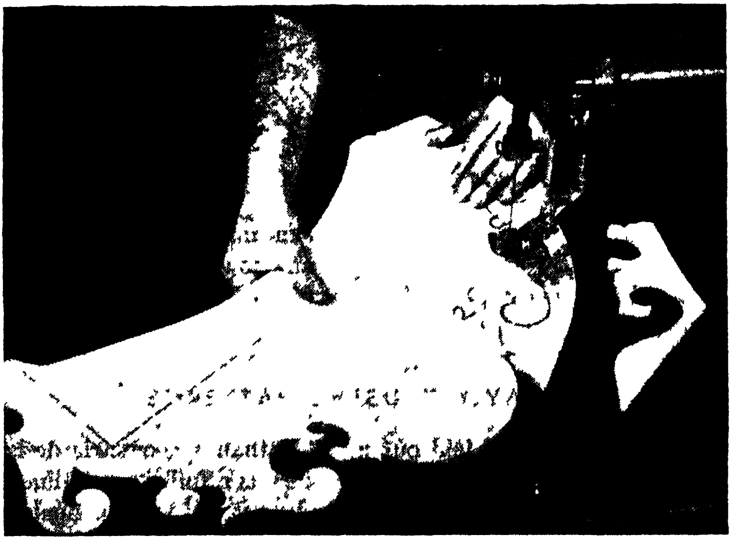


FIG. 4–19. Using a jig saw to cut a scrolled design.

out. When the pattern has been properly placed on the stock, it is traced onto the wood. (See Fig. 4–18.)

A piece of stock which must be symmetrical (with its opposite sides shaped identically) requires the use of a half-pattern. When such a pattern is used, a center line must be drawn on the stock to establish the location of the pattern; then the pattern is placed on the center line. (See Fig. 4–20.) The outline of the pattern is marked on the surface of the stock with a pencil. Then the pattern is turned over and placed on the other side of the center line, and the outlining of the pattern is repeated. A pattern that does not require the use of a center line is shown in Figure 4–21. Such a pattern is the complete outline of the shape to which the stock is cut.

The stock is cut to a rough outline by the use of a coping saw or compass saw, as described on pages 35–36, by sawing a little outside the line to allow sufficient material to smooth the sawed surfaces. (See Fig. 4–19.)

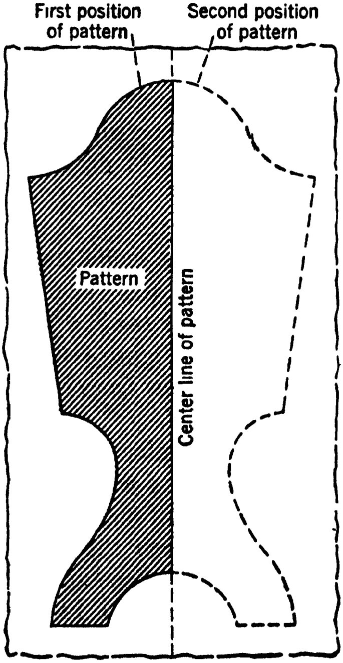


FIG. 4–20. A half-pattern.

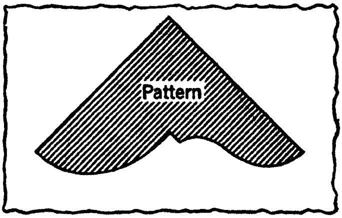


FIG. 4–21. A pattern which does not require a center line.

B. CUTTING

1. CROSSCUT TO A LINE

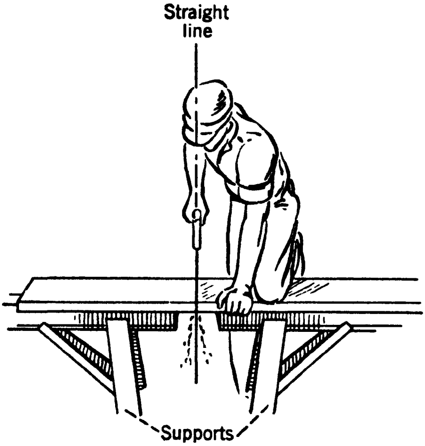


FIG. 4-22. Method of support used in crosscut sawing.

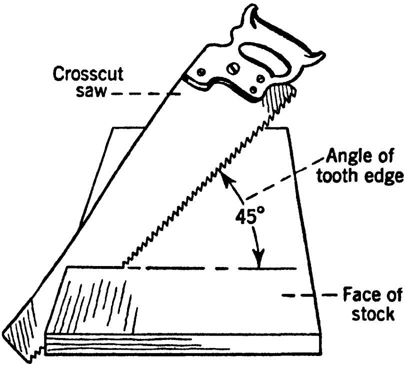


FIG. 4-23. Correct placement of the saw on the stock to be cut.

Use of the crosscut handsaw. When using a crosscut handsaw, the wood or other material being cut should be held securely by means of a holding tool or by the hand or knee. The waste side of the stock should be supported by the hand, or may be supported by a sawhorse in order to prevent the wood from breaking or splitting as the saw cut nears completion. Any support that is used should be near the saw kerf as shown in Figure 4-22 to prevent the saw from binding in the kerf.

The saw is placed on the stock which is to be cut, maintaining an angle of 45 degrees between the tooth edge and the face of the work as shown in Figure 4-23. The position of the arm and body of the person doing the sawing has an important bearing on using the saw properly. The arm of the hand which is holding the saw should form a straight line from the shoulder down to the top of the saw blade. The body should be slightly to the left or right of the saw depending on whether the person is right- or left-handed; but in any case the eye on the same side as the hand which is holding the saw should be in line with the blade as shown in Figure 4–22.

To start the cut, the blade is placed on the line, with the thumb of the free hand supporting the side of the blade. The saw is drawn toward the operator several times until a slight kerf is cut. When this kerf is formed, the hand should be moved away from the blade and a slow, steady, full-stroke back-and-forth movement of the blade started.

A saw should never be forced. If difficulty is encountered when sawing a piece of wood, making it necessary to use force, the fault may lie in the condition of the saw, the way in which the saw is held, or the manner in which the wood is being supported.

2. RIPPING TO A LINE

The hand ripsaw has the same general appearance as that of the hand crosscut saw, as shown in Figure 4–24. This saw, as its name implies, is used to cut *with* the grain. The stock should be held or supported by means of a vise or on a sawhorse, as shown in Figure 4–24. Place the saw on the stock to be cut, maintaining an angle of 60 degrees between the tooth edge and the face of the wood as shown in Figure 4–24*A*. The cut is started and completed in the same manner as for the crosscut handsaw.

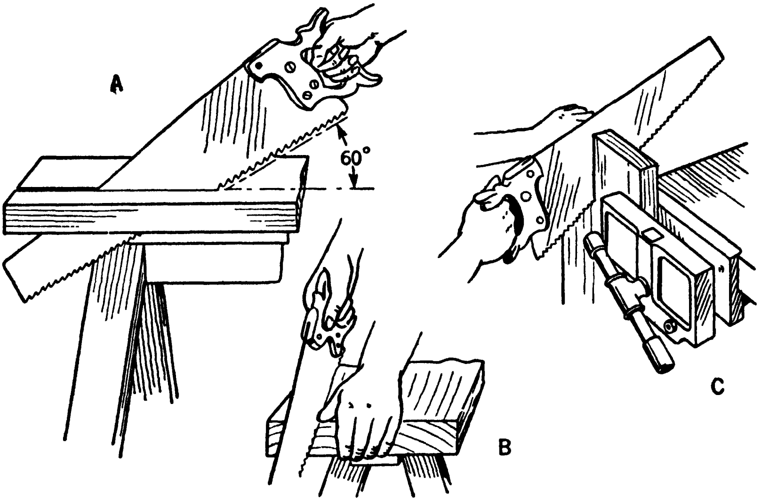


FIG. 4–24. Correct angle between the sawtooth edge and the wood (*A*). Stock supported by a sawhorse (*B*), and by means of a vise (*C*).

3. CUTTING CURVES

To cut a curve in a piece of wood, a saw with a narrow blade must be used. The sharper the curve or sweep to be cut, the narrower the blade must be. Saws designed for this type of work are the coping saw, the web saw, the keyhole saw, the compass saw, and the jig saw.

The coping saw. A coping saw is generally used with a saddle. A *saddle* is composed of two pieces of wood fastened together at right angles. The upright piece is placed in the vise, and the horizontal piece has a V-shaped portion cut away. (See Fig. 4–24.) Saddles are used to support stock in a vise so that a saw such as a coping saw can be used to cut away small pieces of material. The saddle is held in the vise with the surface at a height that will permit the free and easy movement of the saw. The blade should be kept at right angles to the surface of the wood at all times. Each stroke should be as long as possible to avoid overheating of the blade. When using a saddle the work should be shifted so that the saw can follow the curve as it is encountered. Changing the angle of the blade once it has started the cut may result in breaking the blade.

If, when cutting a curve, the saw frame interferes by coming in contact with the stock, the frame can be shifted by means of the swivels in which the blade is placed. This is done by loosening the handle, then turning the swivels by means of the pins until the frame clears the wood. Make certain that the lower swivel is tight before continuing with the work.

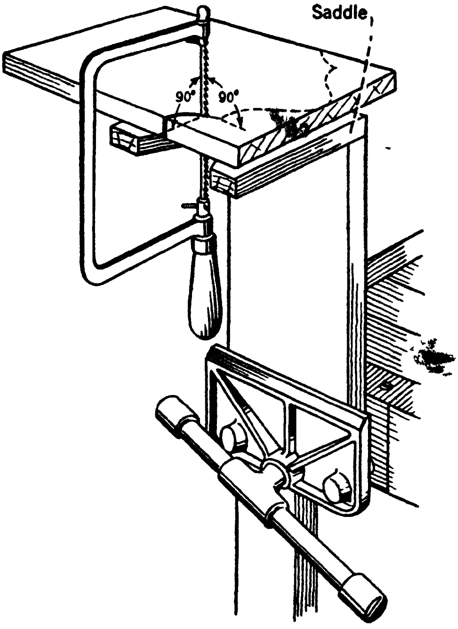


FIG. 4-25. A coping saw and saddle.

Stock which is too large to be held on a saddle may be placed in the vise. In this case it will be necessary to revolve the saw in order to follow the line rather than to move the stock, as when a saddle is used. Care must be taken to keep the blade at right angles to the stock at all times to prevent the blade from binding and breaking.

The web saw. The *web saw* is similar to the coping saw; it is used, in a similar manner, to cut material that is too thick for the coping saw. It has a wood frame with two upright pieces and a third piece between them, forming an *H*. At one end of the uprights there extends between them a rod which can be regulated for length by means of a turnbuckle. Between the other ends of the *H*, the blade is located. The tension on the blade is controlled by the turnbuckle.

Turning saw is a term applied to any saw having a blade which is held in a frame, attached to it at both ends of the blade. It is often applied to a web saw.

The compass saw. When using a compass saw, an angle of 90 degrees should be maintained between the tooth edge and the surface of the wood, as shown in Figure 4–26. When cutting inside circles, a hole must first be bored large enough to pass the point of the saw through. The teeth at this narrow end start the cut; then as the kerf is made longer, the teeth at the wider portion of the blade are brought into action. The sharpness of the curve or arc that is being cut will determine the portion of the blade that can be used. Whenever possible the heavier part of the saw blade should be utilized rather than placing strain on the comparatively weak point, the narrow end.

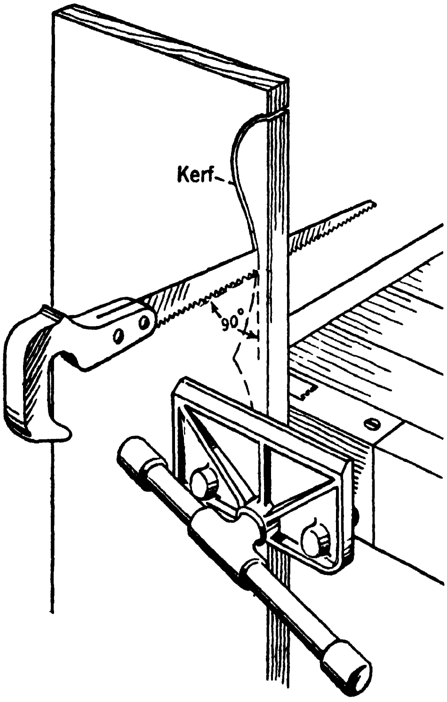


FIG. 4–26. A compass saw.

Finishing of curved surfaces. The finishing or smoothing of the curved surfaces is done with a spoke shave, paring chisel, or paring gouge, as described on pages 43–44, 47–49 and 63. (See also page 170.) Any straight surface is planed to the line with a smooth or block plane.

C. SHAPING

1. SURFACE PLANING

Squaring stock. Planing all the surfaces of rough stock to finished size is the process of *squaring.* The first step is to make a *work face.* This is done by planing one of the faces smooth and straight, using the smooth plane. (See pages 59–61.) The stock is held securely in the vise as shown in Figure 1–81 or on the surface of the bench as shown in Figure 1–83. (See pages 74 and 78.) The surface is tested for straightness with a straightedge such as the blade of the trysquare or framing square, as shown in Figure 4–27. The work face should be tested by placing the straightedge crosswise, lengthwise, and from corner to corner as indicated by the dotted lines in Figure 4–27. If no light shows between the straightedge and the surface of the wood while it is being tested, the work face is finished and should be marked with one line.

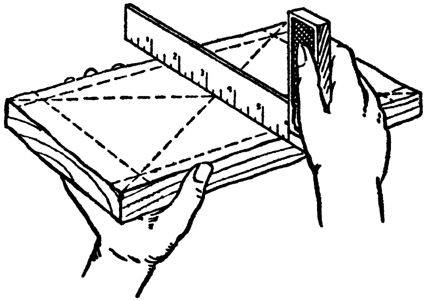


FIG. 4–27. Testing the surface of the stock for straightness with a trysquare.

2. EDGE PLANING

The second step when squaring is to make a *work edge.* This is done by planing one of the edges smooth, straight, and square to the work face, with the stock held securely in the vise as shown in Figure 1–52 on page 52. The edge is tested as shown in Figure 4–28, with the handle of the trysquare held tightly against the work face. The finished work edge is marked with two lines.

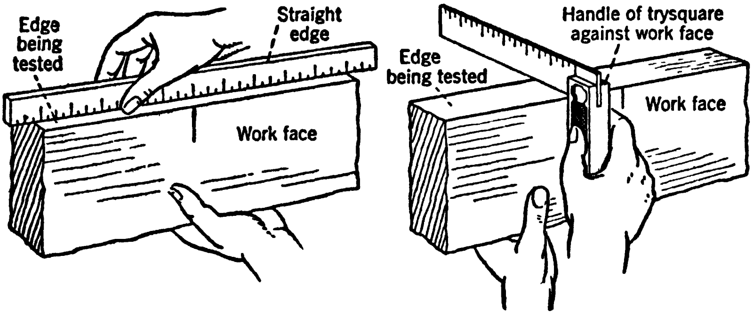


FIG. 4-28. Testing the edge of the stock.

3. END-GRAIN PLANING

The third step is the making of the *work end.* It is done by planing the end smooth, square to the work face, and square to the work edge, with a block plane or smooth plane.

Because of the arrangement of the fibers and cells that form the wood, the planing of the end requires a procedure different from that used when planing the face and the edge. If an end is planed across the entire surface in the one stroke, the fibers at the end of the plane stroke will break. This can be prevented in any one of three ways: (1) by planing from each edge to a little beyond the center; (2) by the use of a chamfer cut on the waste edge; or (3) by bracing the edge with a piece of scrap stock held in place between the vise jaws. The use of the first method is practical when wide pieces have to be planed. (See Fig. 4-29*A*.) The chamfer method is used when there is sufficient stock at the waste edge to allow for the chamfer. (See Fig. 4-29*B*.) The third method will be found helpful when planing the end of narrow stock. (See Fig. 4-29*C*.)

The work end is tested with a trysquare, placing the handle against the work edge to test the end for squareness to the work edge, then placing the handle against the work face to test the end for squareness to this side. The finished work end is marked with three lines.

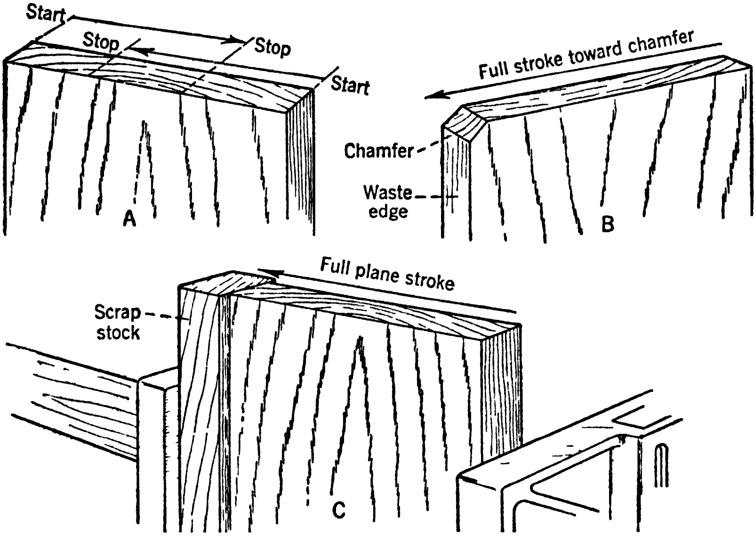


FIG. 4–29. Three methods of end-grain planing.

4. FINISHING TO LENGTH

The fourth step is planing the stock to the required length. The length is measured from the work end, placing the beginning of the rule even with the work end. (See Fig. 4–14*B*.) A line is squared across the faces and edges through the reference mark that establishes the length. The handle of the trysquare is placed against the work face and work edge when doing this. These lines must meet at each corner, and they will do so if the handle of the trysquare is placed as indicated and held tightly against the work face and work edge. The end is planed down to the line, using one of the methods shown in Figure 4–29. The second end is tested in the same manner as the work end.

5. FINISHING TO WIDTH

The fifth step is planing the stock to the required width. The width is marked off with the marking gage, setting and using the gage as shown in Figures 1–6 and 1–8. The line establishing the width is made on the faces and ends. The head of the marking gage is held against the work edge when scribing the line. The second edge is planed down to the line and tested in the same manner as the work edge. (See Fig. 4–28.)

6. FINISHING TO THICKNESS

The sixth step is planing to thickness. The required thickness is marked off with the marking gage, gaging from the work face. The second face is planed down to the gage line and tested in the same manner as the work face. (See Fig. 4–27.)

7. AUGER–BIT "THROUGH" BORING

When boring holes through a piece of wood with an auger bit or an expansive bit, it is necessary to bore from both sides; or, if bored through from the one side, the stock must be backed up with a piece of scrap wood in order to prevent the splitting of the wood as the bit breaks through. (See Fig. 1–22, page 23.)

The shaping of a curve on the edge of a piece of wood or of a circular cut within the wood can often be done with an auger bit, provided the curve to be shaped is an arc or part of a circle. Auger bits come in sizes ranging from $\frac{3}{16}''$ upward, and any curve having a diameter equal to that of an auger bit can be shaped by boring a through hole. Curves that are of a larger diameter than that of available auger bits can be shaped with the aid of an expansive bit, which can be regulated to bore holes up to 3″.

8. TWIST BIT AND TWIST DRILL

The twist bit and twist drill are seldom used in woodworking except for boring small holes for screws or bolts. Occasionally a twist bit or twist drill is employed when it is necessary to use a coping saw within the limits of the stock. A small hole is then bored within the area that is to be removed so that the blade of the coping saw can be passed through.

When boring a hole with either the twist bit or twist drill, it is not necessary to bore from each side as when the auger bit is used.

9. COUNTERSINKING

Countersinking is the shaping of a hole or depression to conform to the shape and thickness of a *flat or oval screwhead;* it is done with a cone-shaped cutter called a *countersink.* The angle at which the depression is cut is standard, being controlled by the countersink, which in turn is made to conform with the angle of the underside of the screwhead. The purpose of countersinking is to permit the head of a flathead screw to set flush with or slightly below the surface of the wood.

A hole that is to receive a flathead or ovalhead screw is first bored as explained on page 16; then it is countersunk on the surface which the screw enters. The depth to which a hole is countersunk will depend on the thickness of the screwhead. This thickness is measured from the point where the body of the screw ends and the head starts, to the widest part of the head.

The depth to which a countersink will bore can be controlled with the aid of a special *bit gage.* Such a gage is attached to the shank of the countersink. The bit gage is used only when there are several holes to be countersunk to the same depth, since the gage is set after the first hole has been countersunk.

To countersink a hole, the countersink bit is placed in a brace as described on page 17. The stock into which the countersink is to be made is held in the vise or to the top of the bench by means of a clamp. The point of the countersink is placed in the screwhole. Then with the brace held in such a position that the shank of the countersink is parallel to the direction in which the screwhole was bored, the hole is countersunk by turning the brace in a clockwise direction. The depth of the countersinking of the first hole is determined by trial-fitting the screw. Once the first hole has been countersunk, the bit gage can be set to duplicate the depth. (See also pages 198–200.)

10. CURVES

The shaping of a curve involves the use of any one of a number of tools, depending on the sweep of the curve and whether the curve is concave or convex. Tools most commonly used for shaping a curve are: plane, spoke shave, chisel, rasp, and file. The manner in which these tools are manipulated is described in Unit I.

When it is necessary to shape a convex surface having a broad sweep, the plane, spoke shave, or paring chisel is used. If this surface is the face or edge, the planing or chiseling is done in the direction of the grain. If the curve is on an end, the work must be done from both edges, or faces, toward the center. A convex surface with a short sweep can best be shaped with a spoke shave, paring chisel, or the flat side of a rasp or file. The direction of the grain must always be taken into consideration. Cutting must always be done with the grain, or from the edge to the end if the curve is on the end of the wood. Concave surfaces that have broad sweeps are shaped with a spoke shave or the round side of a rasp or file. When such a surface has a sweep too small for a spoke shave, the rasp or file should be used.

11. CHAMFERS AND BEVELS

A *chamfer* is an inclined surface extending between adjacent sides. (See Fig. 4–30.) A chamfer may be used to prevent the edge of the wood from breaking, when planing an end (Fig. 4–29*A*), to shape a piece of wood (Fig. 4–30*B*), or to decorate a piece of wood (Fig. 4–30*C*). A chamfer should be laid out to the size required by using the various layout tools as described on pages 4–15. Cutting a chamfer is generally done with a plane or chisel. (See Figs. 1–41 and 1–62.) Small chamfers may be cut with sandpaper.

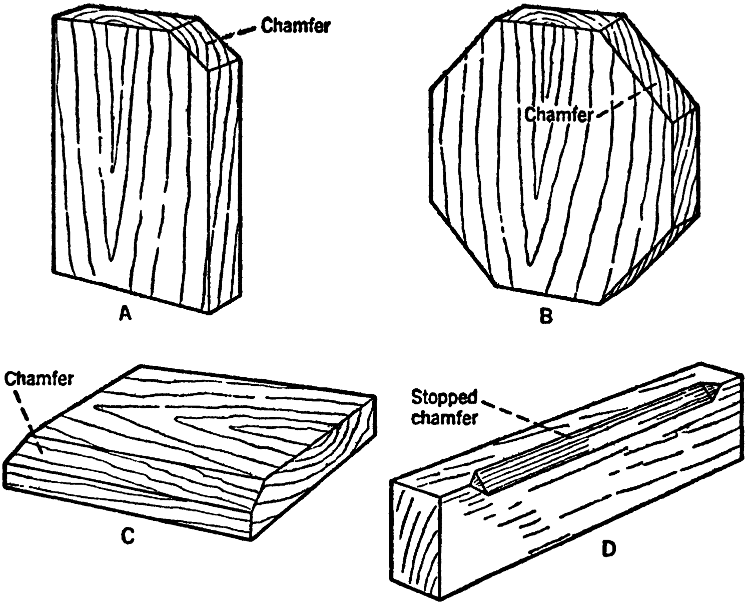


FIG. 4-30. Chamfers.

A *bevel* is an inclined surface other than 90° extending between opposite sides. (See Fig. 4-31.) The bevel angle is laid out with the aid of the T-bevel as described on pages 8-9. A plane is used to cut the bevel. The bevel should be tested frequently with the T-bevel as the planing is done.

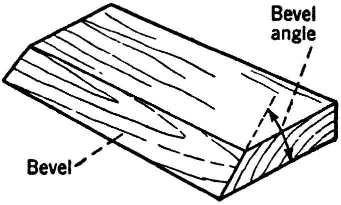


FIG. 4-31. A bevel.

D. JOINTING

1. THE BUTT JOINT

A butt joint is formed by joining two pieces of stock without fitting one piece into the other. (See Fig. 4-32.) The pieces so

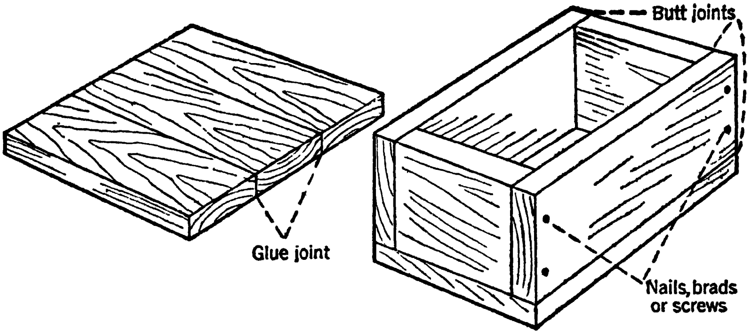


FIG. 4–32. Butt joints.

joined may be held together by means of glue, nails, or screws. The glued butt joint is most frequently used when joining two or more boards together, edge to edge, in order to produce a wide panel. The success of such an operation depends on the planing of the butting edges, that is, the edges touching each other. The butt joint may be strengthened by the use of dowels, as explained on pages 209–211.

When such a panel is to be made up, the stock required should be cut from a rough-stock list which allows the necessary waste for planing. The pieces are placed edge to edge on the bench and arranged so that the annual rings of each end are in opposite directions. (See Fig. 4–33.) The relative position of each edge is marked by lettering the butting edges.

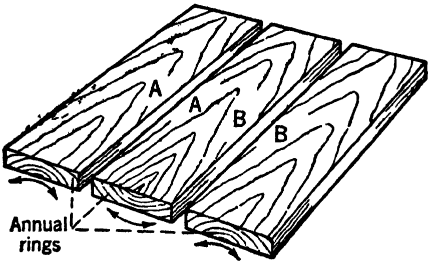


FIG. 4–33. Correct placement of stock to make a wide panel.

A work face is planed on each piece, following the procedure outlined on page 165. The second step is to dress the butting edge of each piece, making each one smooth, straight, and square to the work face. The edges which are marked alike to be joined must be tested by placing them together to see if they fit tightly. The slightest space between the butting edges will produce a poor joint. Long pieces of stock that are to be joined will produce a more permanent joint if the butting edges are slightly concave.

Of all the joints, the butt joint is the weakest, for it depends for its strength solely upon the glue, screws, or nails used to hold it together. The strength of a butt joint may be increased by the use of dowels, as explained on pages 151–153.

Before glue is applied to the edges, the work is given a final test by placing a clamp across the center of the pieces and drawing them up tightly. They should fit tightly at the ends so that the boards cannot be moved by pressing on them with the fingers.

2. LAP JOINTS

Lap joints are formed by one piece of stock extending over another, with a section of each removed to fit them together. The most common lap joints are the end-lap, half-lap, middle-lap, and cross-lap joints. (See Fig. 4–34.)

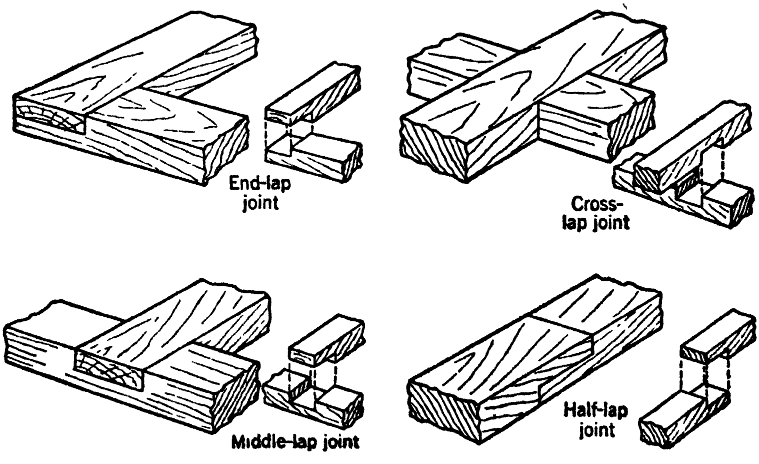


FIG. 4–34. Lap joints.

The end-lap joint. The stock which is to be joined together by means of an end-lap joint is cut and dressed to size, as outlined on pages 151–152 and 165–168. The stock is arranged with the work faces up, and the ends which are to be cut to form the joint should be marked *A* and *B*. (See Fig. 4–35.)

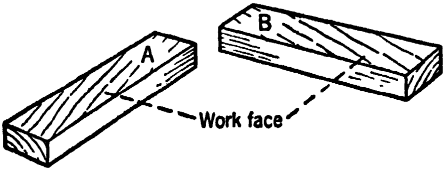


FIG. 4–35. First step in making an end-lap joint.

The second step is to lay out the length of the cut, which must be equal to the width of the piece that is to set in it. This is done by placing piece *B* on the work face of piece *A*, with the edges and ends flush. A knife mark is made on *A*, keeping the knife as close as possible to the edge of piece *B*. (See Fig. 4–36.) Piece *B* is now placed on the bench with the work face down, and the operation is repeated, using piece *A* to obtain the required length of the cut.

In the third step, a knife line is cut across the work face of *A* and the second face of *B*, passing through the knife mark which was made previously. This line is continued halfway across both edges. (See Fig. 4–37.)

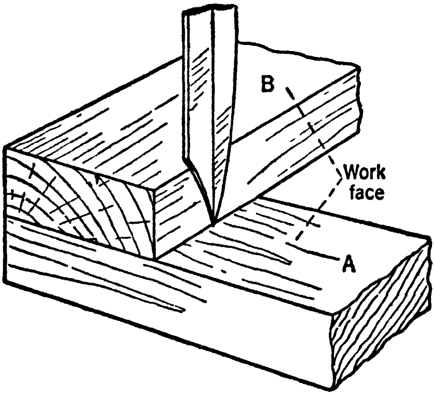


FIG. 4–36. Second step in making an end-lap joint.

The fourth step is laying out the depth of the cut with the marking gage. The gage is set for half the thickness of the stock. A gage line is made along each edge, extending from the knife line to and across the end; this must be done on both pieces. The section of each piece to be removed is shaded as shown, and the pieces are placed over one another to check the layout. (See Fig. 4–38.)

The first step in cutting the joint is to make a V-groove across the face of each piece. (See Fig. 4–39.) This is done with a chisel. The purpose of the V-groove is to guide the backsaw and start it flush with the line. The backsaw is placed in the V-groove and the stock is cut to the gage line. (See Fig. 4–40.) The V-groove will only aid in starting the cut at the proper place. The saw must be kept straight and parallel to the vertical knife lines on the edges.

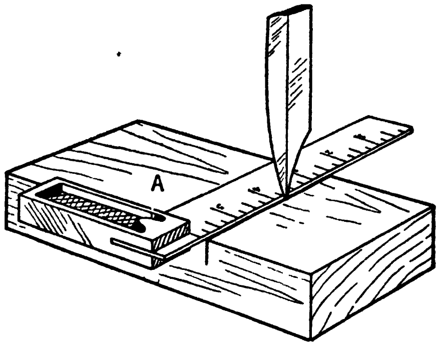


FIG. 4–37. Third step in making an end-lap joint.

The section to be removed is cut away with a chisel, as described on page 43. The greater part of the stock can be cut away by using a mallet to drive the chisel, cutting from the end toward the saw cut. (See Fig. 4–41.) The finishing cut is made at the gage line, using a paring chisel across the grain.

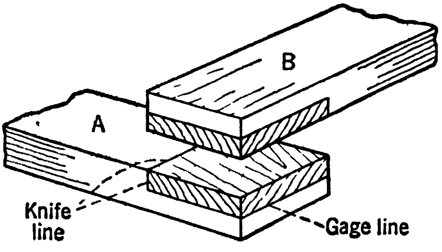


FIG. 4–38. Fourth step in making an end-lap joint.

The end-lap joint is usually fastened together with glue, screws, or nails. It is strongest when used in such a manner that the force exerted on either member is toward the point where the pieces join. It is often used in the construction of frames, instead of the mortise-and-tenon joint.

The half-lap joint. The half-lap joint is laid out and cut in the same manner as the end-lap joint. The length of the cut may be varied to meet special requirements, but in any case the length of the cut must be identical on both pieces.

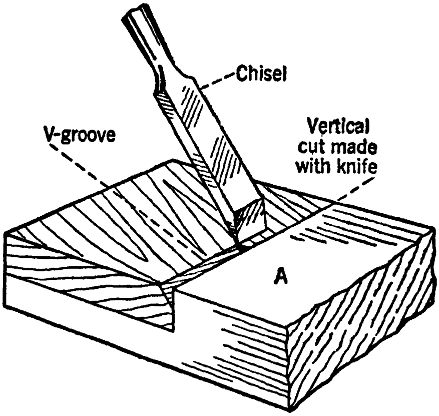


FIG. 4–39. Making a V-groove in preparation for cutting an end-lap joint.

The middle-lap joint. A middle-lap joint is formed when the end of one piece extends over to join the other at some point between the ends. The stock is cut and dressed to the required size as described on pages 151–152 and 165–168. The pieces to be joined are placed on the bench with the work faces up, and marked as shown in Figure 4–42.

The location of the dado to be cut in piece *A* to receive piece *B* can best be established by squaring the center line of the dado across the face. (A *dado* is a flat groove across the grain of a member, as in piece *A*, Figure 4–44.) This center line is the center line of the dado and does not necessarily indicate the center of the stock. Across the end of piece *B* a center line is drawn.

The width of the dado is marked off by placing piece *B* on the face of piece *A* so that both center lines coincide. A knife mark is made on the face of piece *A* as close as possible to the edges of piece *B*. (See Fig. 4–43.) Knife lines are squared across the work face through these knife marks. They are carried halfway across the edges.

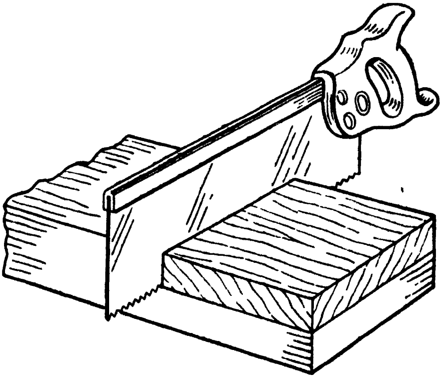


FIG. 4–40. Saw placed in the V-groove in cutting an end-lap joint.

Piece *B* is laid out as an ordinary end-lap joint, marking off the required length of the cut on the side opposite the work face.

The depth of the cut on both pieces is marked off with a marking gage. The gage is set for half the thickness. Gaging is done from the work face on both pieces. The gage lines on *B* are on the two edges extending from the end to the knife line as well as across the end. (See Fig. 4–44.) The sections that are to be removed should be shaded, then the pieces placed over one another to check the layout.

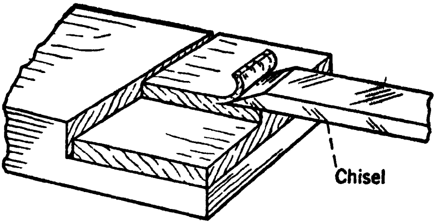


FIG. 4–41. Cutting the stock away with a chisel.

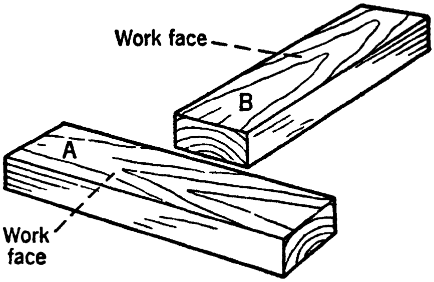


FIG. 4–42. Correct placement of pieces to be joined in making a middle-lap joint.

The first step when cutting the dado in piece *A* is to cut V-grooves across the face to guide the saw. (See Fig. 4–45.) Saw cuts are made by placing a back-saw in the V-grooves and sawing down to the gage line. If the dado

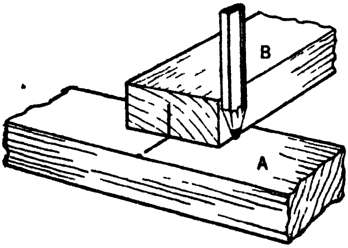
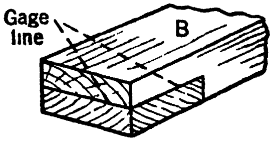


FIG. 4–43. Marking off the width of the dado.



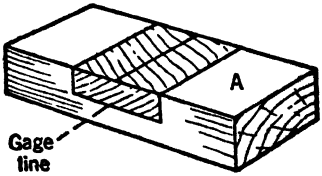


FIG. 4–44. Gage lines.

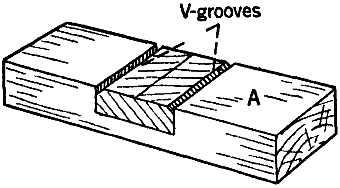


FIG. 4-45. V-grooves to guide the saw in cutting a dado

is wide, several saw cuts can be made within the area of the stock to be removed.

The removal of the stock within the limits of the saw cuts is done with a chisel, working from both edges toward the center. (See Fig. 4–46.) The dado is finished by using a paring chisel or with a special tool which is called a *router*.

The cutting of piece *B* to fit in the dado is done in the same manner as described for the end-lap joint.

The middle-lap joint is used when one member or piece of stock is to be fastened to another member at a point between the ends. There is no strain on the fasteners used to hold these members together if the pressure is applied to the edges or the face of the member that is set in the dado. Crosspieces in a frame are frequently joined to the outside frame members by means of this joint.

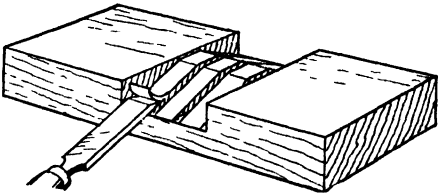


FIG. 4–46. Removing stock with a chisel.

The cross-lap joint. The cross-lap joint is formed when two pieces cross one another so that the surfaces are flush. They may cross one another at any point and at any angle. The two pieces of stock are cut and dressed to the required size, as previously described.

The first step when laying out a cross-lap joint is to place the pieces with the work face of one *up* and the work face of the other *down*. (See Fig. 4–47.) The center of the joint is located and a line squared across the work face *A* of one piece and the side opposite the work face *B* of the other. Center lines are also square across one end of each piece from face to face.

The next step is to place piece *B* on the face of *A* so that the center lines on the end and face coincide. (See Fig. 4–43.) Knife marks are made on the face of *A* as close as possible to the edges of piece *B*. (See Fig. 4–43.) This establishes the width of the dado that must be cut in piece *A* to take piece *B*. The operation is repeated to lay out the width of the dado that is to be cut in piece *B* to take piece *A*.

Knife lines are squared across the face of each piece through the knife marks that located the limits of the dado. These knife marks are carried halfway across each edge. The depth to which the dado on each piece is to be cut is marked off with the marking gage. The gage is set for half the thickness of the stock and a line is gaged from the work face of each, extending between the knife lines. The cutting of the dadoes to form the joint is done in the same manner as in the middle-lap joint.

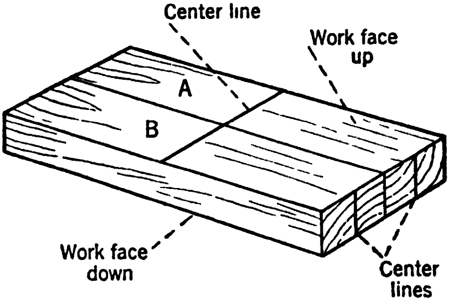


FIG. 4–47. Placement of pieces in laying out a cross-lap joint.

Cross-lap joints that are to be made at any angle other than 90 degrees should be laid out with a T-bevel rather than with a trysquare. The method of laying out and cutting such a cross-lap joint is identical to that just described.

Of all the lap joints, the cross lap joint is the strongest. It relies least on the glue, screws, or nails used to fasten the members together. Such a joint will withstand pressures in any direction except one, without depending on the fastener that holds it together.

3. THE RABBET JOINT

A rabbet joint is formed by cutting a recess along the edge or end of one piece of wood to receive the edge or end of another piece which is cut to fit it. (See Fig. 4–48.) The two pieces to be joined by a rabbet joint are squared to the required size as outlined on pages 151–152.

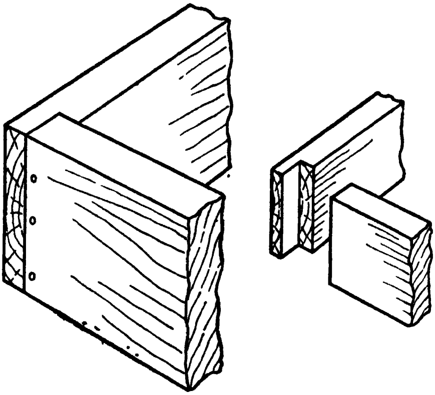


FIG. 4–48. Formation of a rabbet joint.

The two pieces are placed on the bench in their relative position. In Figure 4–49 the piece into which the rabbet is to be cut is marked *A*; the other piece is marked *B*. The width of the rabbet is equal to the thickness of the stock which is to set in it. This is laid out by placing piece *B* on the work face of *A*, with the face of *B* flush with the end of *A*. A knife mark is made on the face of *A* as close as possible to the inside face of *B* to locate the width of the dado. (See Fig. 4–50.) A knife line is cut across the work face and part way across the two edges, using the trysquare to guide the knife.

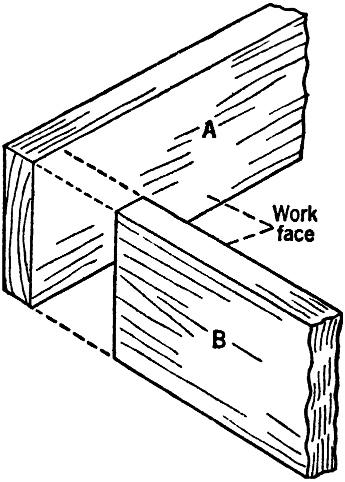


FIG. 4–49. The piece into which the rabbet is to be cut (*A*); the other piece (*B*).

The depth of the rabbet is laid out, using the marking gage. (Gaging is done from the work face.) The gage is set for the required depth. The gage line extends across the end and on the two edges from the end to the knife line. The section which is to be removed is shaded. (See Fig. 4–51.) The layout is checked by placing piece *B* on the shaded section.

A V-groove is made across the face of the stock, using the chisel to cut down to the bottom of the knife line. The chisel cut must be made from the section of

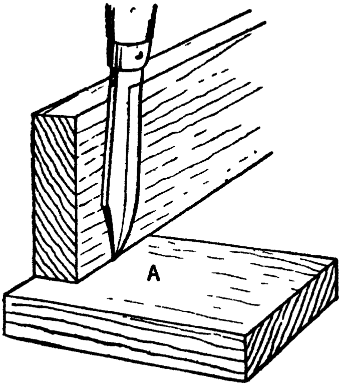


FIG. 4–50. Locating the width of the dado by making a knife mark on the face of *A*.

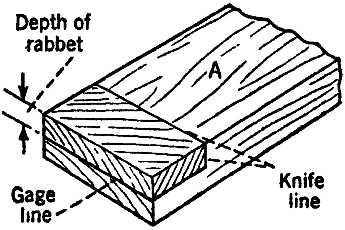
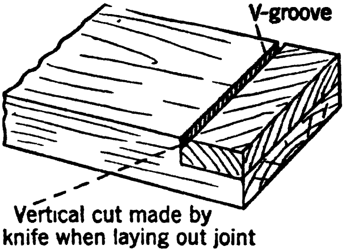


FIG. 4–51. The section to be removed is shaded.



Vertical cut made by knife when laying out joint

FIG. 4–52. V-groove and vertical cut.

the stock which is to be removed. (See Fig. 4–52.)

The shoulder cut is made by placing the backsaw in the V-groove and cutting a kerf down to the gage line. The saw should be kept straight and parallel to the lines on the edges.

The rabbet is cut to the required depth with a chisel. The cutting edge of the chisel is placed on the end of the stock, well above the gage line, and struck lightly with a mallet. (See Fig 4–53.) The rabbet is finished to the gage line with a paring chisel,

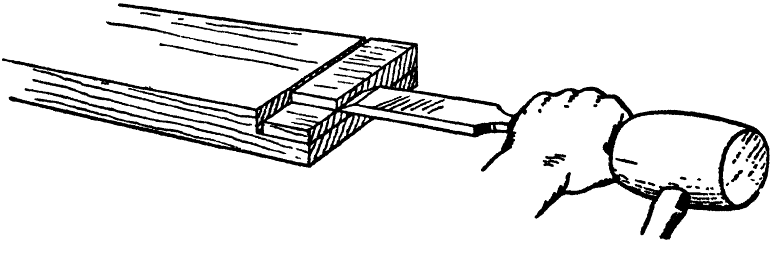


FIG. 4–53. Cutting the rabbet with a chisel.

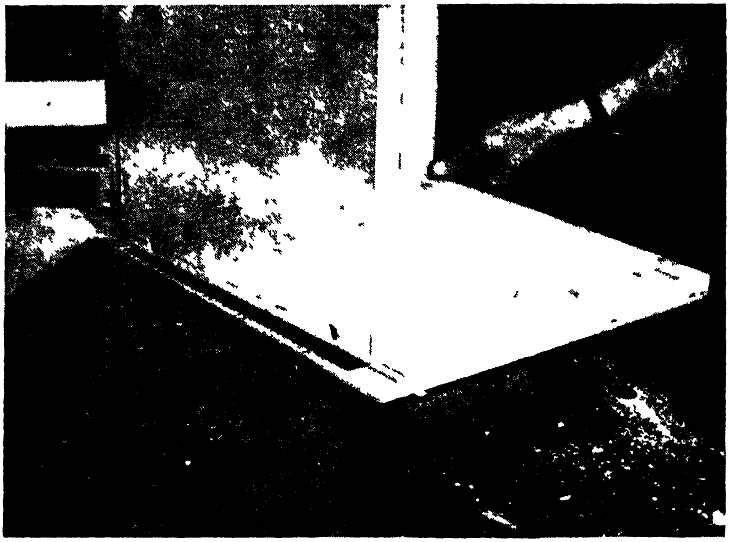


FIG. 4–54 A rabbet joint used in cabinet construction to reduce to a minimum the visible end grain

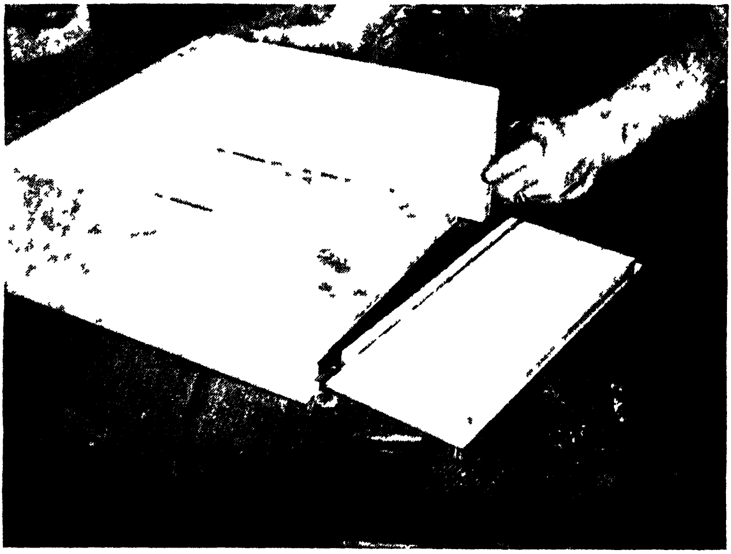


FIG. 4–55 Drawer construction showing the use of a rabbet joint.

working from both edges toward the center. (See Figs. 4–54 and 4–55.)

The strength of a rabbet joint is the result of cutting the pieces to be joined in such a manner that the strain is at right angles to the nails or screws used to fasten the members together. This type is often used to reduce to a minimum the amount of end-grain exposure.

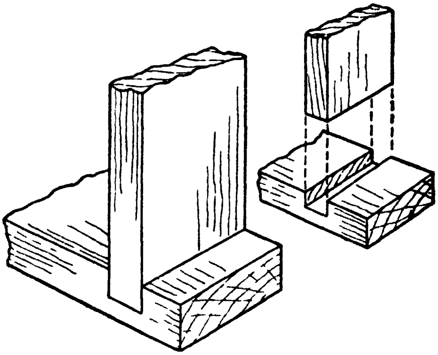


Fig. 4–56. Formation of a dado joint.

4. THE DADO JOINT

The pieces that are to be joined by means of a dado joint are cut and squared to the required size as outlined on pages 151–152. A dado joint is formed by cutting a recess across the grain of a piece of wood from edge to edge or face to face to receive a second piece. (See Fig. 4–56.) It differs from the rabbet joint in that it has two shoulders, or vertical cuts, while the rabbet which is cut along the edge or end of a board has only one. The two pieces are placed on the bench in their relative positions; the one in which the dado is to be cut is marked *A*, the other *B*. (See Fig. 4 57.)

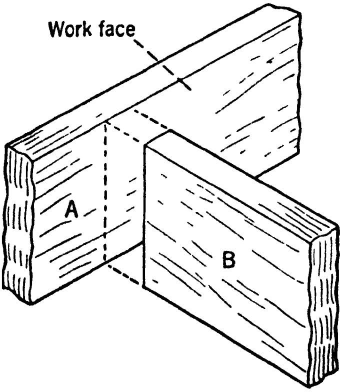


Fig. 4–57. Piece of wood in which dado is to be cut (*A*); the other (*B*).

The center of the dado is located on piece *A* and a line is squared across the face. A center line is gaged along the end of piece *B*. Piece *B* is placed on piece *A* so that the center lines coincide. Knife marks are made on the face of piece *A* as close as possible to the faces of piece *B* to establish the width of the dado. (See Fig. 4–58.) Knife lines are cut across the faces through the knife marks and part way down the edges. The trysquare is used to guide the knife. The handle of the trysquare should be held tightly against the work edge when cutting the lines across the face, and against the work face when cutting the lines across the edges.

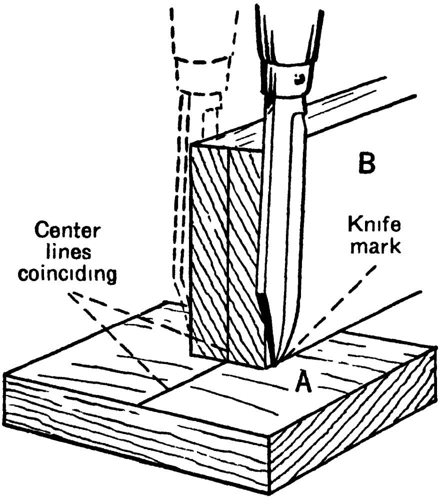


FIG. 4–58. Finding the width of the dado with knife marks.

The depth of the dado is marked off with a marking gage, setting the gage for the required depth and gaging from the work face. The gage line should extend between the two knife lines on each edge. (See Fig. 4–59.) The section of the stock which is to be removed to form the dado is shaded, and the laying out of the cut tested for accuracy by placing piece *B* in position. The dado is cut as shown in Figure 4–45, and as described for cutting the middle-lap joint.

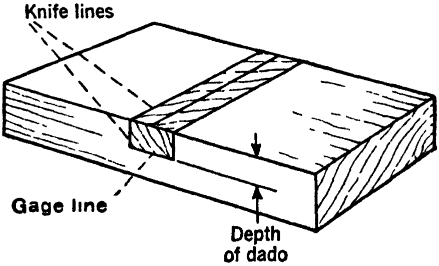


FIG. 4–59. Gage line extending between the two knife lines.

5. THE MITER JOINT

The miter joint is a form of butt joint, differing only in that the pieces which are joined are cut at an angle other than 90 degrees. It is produced by making a bevel cut on the ends or edges of the pieces which are to be joined. It relies for its strength on the fasteners, and is therefore no stronger than the butt joint.

Pieces of equal width or thickness that are to be mitered must have the bevels which are to be joined cut at the same angle. (See Fig. 4-60.) The angle at which the cut is made is half the angle formed by the two pieces when joined. The stock that is to be used is cut and squared to the required size as described on pages 151–152.

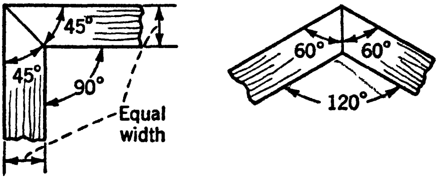


Fig. 4-60. Stock of equal width to be mitered.

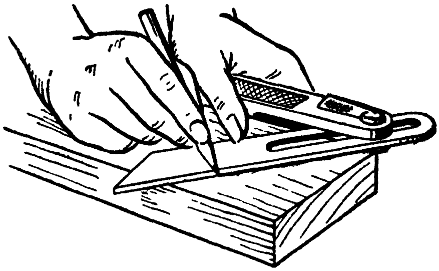


Fig. 4-61. Using the bevel a line is drawn across the face of the wood.

The pieces to be joined by a miter joint are arranged on the bench in their relative positions. A T-bevel is used to lay out the angle at which the miter is to be cut. The T-bevel is set as described on pages 8–9. A line is drawn across the face of the wood, using the bevel. (See Fig. 4-61.) The line is carried across the edge with a trysquare. (See Fig. 4-62.)

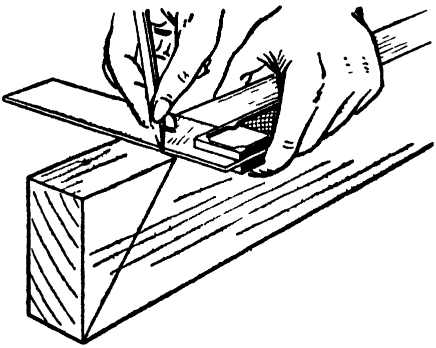


Fig. 4-62. A trysquare is used to carry the line across the edge.

The miter, if at the end of the wood, can be cut with a backsaw. The cutting should be done slightly beyond the line to allow for trimming the bevel with a block plane. (See Fig. 4-63.) The angle at which the miter has been cut and planed is tested with the T-bevel, as shown in Figure 1–4.

Miters along the edge or the end of the wood can be cut entirely with a plane, laying them out and testing them in the manner described in the previous paragraphs. (See Fig. 4-64.)

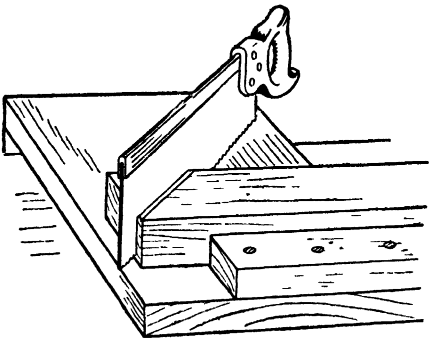
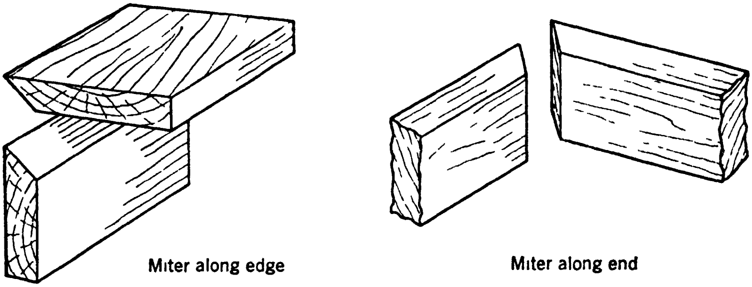


FIG. 4–63. Cutting.



Miter along edge

Miter along end

FIG. 4–64. These miters can be cut entirely with a plane.

6. THE MORTISE-AND-TENON JOINT

The mortise-and-tenon joint is one of the best methods of joining two pieces of wood. It consists of two parts: the *mortise*, which is a rectangular hole cut into one member; and the *tenon*, which is a rectangular projection the same size as the mortise, cut on the end of the other member. It is used when joining the end of one piece to the face or edge of another.

The mortise-and-tenon joint has many variations, each of which has a special name: blind, stub, through, open, haunched, keyed, and wedged. (See Fig. 4–65.) Basically, however, the method of laying out and cutting all mortise-and-tenon joints is the same.

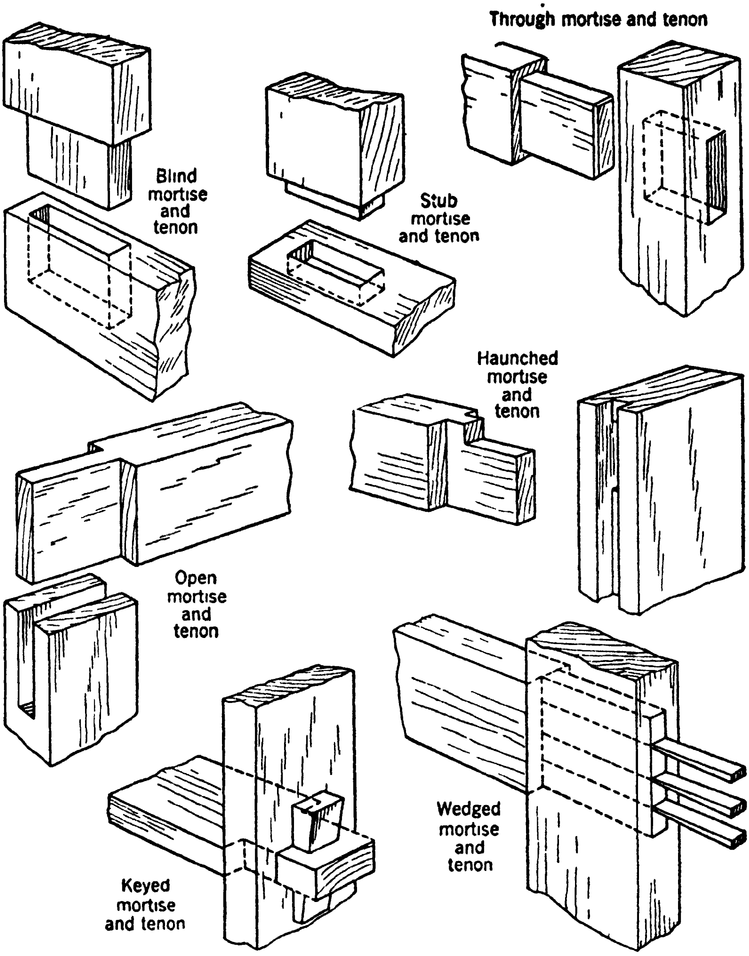


FIG. 4–65. Variations of the mortise-and-tenon joint.

The pieces which are to be joined are cut and squared to the required size, as outlined on pages 151–152. The pieces are arranged in their relative positions and marked *A* and *B*. The mortise is to be cut into the edge of *A*, and the tenon is to be cut on the end of *B*.

The length of a tenon varies from ½″ to 2″, depending on the size of the member into which it is being fitted and on the type of mortise-and-tenon joint that is to be made. The thickness of the tenon is usually one-third the thickness of the stock on which it is cut. Before the actual laying out can be undertaken, the size of the mortise must be determined as well as its distance from the end of the stock.

A center line indicating the center of the mortise is drawn on the edge of the stock. The location of the upper end of the mortise is established by measuring in the required distance from the end and squaring a line across the edge. The length of the mortise is measured from this line. A second line is squared across the stock at this point, establishing the length of the mortise. The width of the mortise is laid out with the mortise gage set as outlined on pages 11–12. (See Fig. 4–66.) The tenon is laid out by first measuring off the required length from the end and squaring a knife line around the stock. The handle of the trysquare should be kept against the work edge and work end.

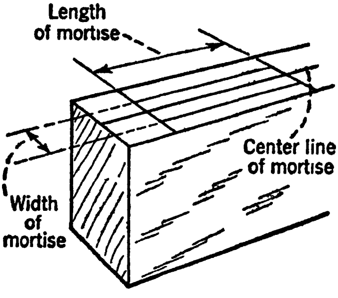


FIG. 4–66. Length and width of the mortise.

Using the mortise gage without changing the setting of the double pins, mark off the required thickness of the tenon, gaging lines on the end and down the two edges from the end to the knife line. The width of the tenon, which is the same as the length of the mortise, is laid out with the mortise gage. The double pins are set for the required dimension, and the head is set for the distance from the edge that the gage lines are to be made. The gage lines are made across the end and on the faces, extending from the end of the stock to the knife line. (See Fig. 4–67.) The portion of the stock that is to be removed when cutting the mortise and the tenon should be shaded. The layout is checked for accuracy.

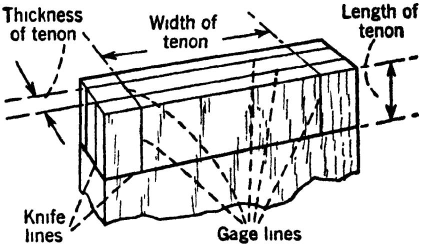


FIG. 4–67. Gage lines across the end and on the faces of the stock.

Cutting the mortise. The mortise can be cut by boring a series of holes within the area that is to be removed. The remainder of the wood is cleaned out with a chisel. Since most mortises are cut relatively deep, the use of a bit to remove the major portion of the stock will make the work considerably easier.

Use an auger bit of the same diameter as the mortise. The stock is held in the vise, and a series of holes are bored within the limits of the mortise. The holes should be bored at the ends of the mortise first. When boring the holes, place the point of the bit on the center line, carefully holding the bit at right angles to the surface throughout the operation. The holes are bored to the required depth of the mortise, which should be about $\frac{1}{8}''$ deeper than the length of the tenon.

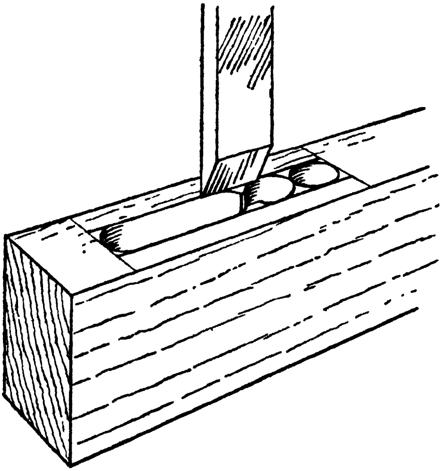


FIG. 4–68. Removing the wood between the holes with a paring chisel.

The wood left between the holes is removed with a paring chisel.

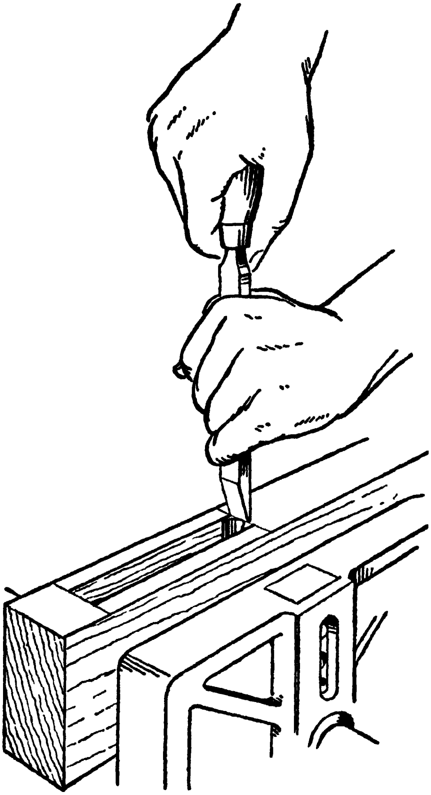


FIG. 4–69. Cleaning the ends of the mortise with a paring chisel.

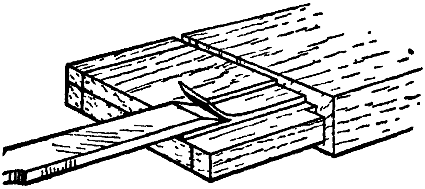


FIG. 4–70. Removing waste with a paring chisel.

(See Fig. 4–68.) The chisel must be held perpendicular, with the bevel side toward the center of the mortise. Keep the sides of the mortise straight and do not cut beyond the gage line. Clean the ends of the mortise with a narrow paring chisel. (See Fig. 4–69.)

Cutting the tenon. A V-groove is cut across the faces and the edges to aid in starting the shoulder cuts. The cutting of the groove is done from the stock to be removed toward the knife line. The shoulder cuts are made to the depth of the gage lines, sawing across the faces first and then across the edges.

The tenon must be fitted to the mortise, and should be tested from time to time as the paring of each cheek progresses. The cheeks of the faces are cut with a chisel by a series of paring cuts until the waste is removed down to the gage line. (See Fig. 4–70.) The cheeks on the edges are cut in the same manner. (See Fig. 4–71.)

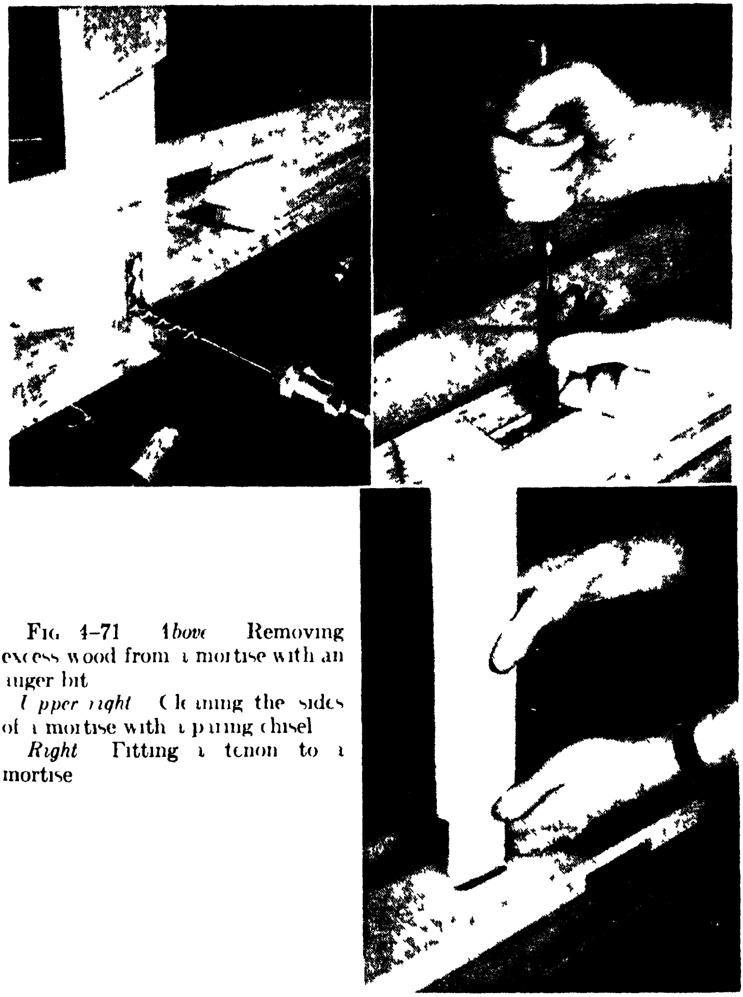


FIG. 4-71 *Above* Removing excess wood from a mortise with an auger bit

Upper right Cleaning the sides of a mortise with a paring chisel

Right Fitting a tenon to a mortise

E. ASSEMBLING

The act of fastening together two or more pieces of stock that have been prepared by any of the various woodworking operations is known as *assembling.* The most commonly used fasteners for this are nails, screws, bolts, glue, and dowels. Which type to use depends on the material that is to be assembled, the manner in which the pieces join, the use to which the assembled unit is to be put, and the permanence of the structure. A knowledge of the various types of fasteners, their limitations, and how they are applied will help in deciding when each should be used.

1. NAILS

Nails are pieces of metal consisting of a shank, a head, and a point. The *shank* may be round or rectangular in cross section, and may be tapered or straight. The *head* may be large or small, but in any case it is larger than the shank. The *point* may be long and sharp; short and sharp; blunt and tapered; or blunt. Nails are made of iron, brass, copper, and steel. They may be cast, cut, wrought, or made from wire. Their characteristics have a definite bearing on their holding power and on the use to which each type of nail is put.

Nails most commonly used by the woodworker are: tacks, escutcheon pins, brads, finishing nails, casing nails, common wire nails, and cut nails. (See Fig. 4–72.) Cut nails and common wire nails are used in rough carpentry and in building construction. Casing nails, finishing nails, and brads are used for interior trim, furniture, and light, inexpensive cabinetwork. Escutcheon pins, which are round-headed nails, are used to fasten escutcheons (ornamental plates used over keyholes and with drawer pulls) for ornamentation, and in upholstery. Tacks are used in upholstery.

Sizes of nails. The size of a nail is determined by its length. In some types a definite relationship exists between the length and the diameter of the shank. To illustrate this point, examine

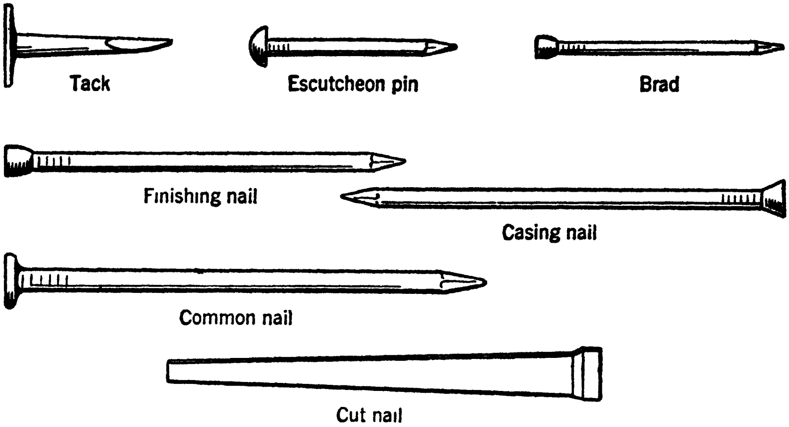


FIG. 4-72. Types of nails used by the woodworker.

a 2″ common wire nail, a 2″ casing nail, and a 2″ finishing nail. It will be found that the wire nail is made of $11\frac{1}{2}$-gage wire, the casing nail of $12\frac{1}{2}$-gage wire, and the finishing nail of 13-gage wire. While all three are the same length they are of different diameters, the common wire nail being the thickest and the finishing nail the thinnest.

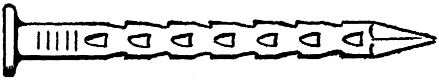
The method of designating the size of most nails is the English penny system. The word *penny,* the abbreviation for which is *d.* (as used to designate nail sizes), refers to the pound weight of 1000 nails. Nails weighing two pounds per thousand would be called twopenny nails. The relationship of length to the penny system and of gage size to wire nails is shown in Table 6 in Appendix A.

Some wire nails, such as brads, escutcheon pins, and certain types of common nails, are not sized by the penny but by their length and gage number; for example, a 1″ brad may be a 1″ #20 or a 1″ #16. While both are of the same length the #20 brad would be .0348″ or about $\frac{1}{32}$″ in diameter while the #16 would measure .0648 or $\frac{1}{16}$″ in diameter.

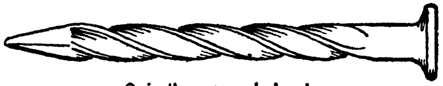
Tacks are sized by their weight per thousand. A thousand $\frac{1}{8}$″

tacks will weigh 1 ounce; $\frac{1}{8}''$ tacks are therefore known as 1-ounce tacks. Tacks are made in lengths from $\frac{1}{8}''$ to $1\frac{1}{8}''$, in sixteenths of an inch, with their size designation starting at 1 ounce and ranging up to 24 ounces.

Holding power. The holding power of a nail, which is of prime importance to the woodworker, depends on several factors. The first of these is the moisture content of the wood. Most types of nails, when driven into green or unseasoned wood, lose a large part of their holding power if seasoning takes place later. This can be overcome by the use of barbed or spirally grooved nails. (See Fig. 4-73.)



Barbed shank



Spirally grooved shank

FIG. 4-73. Barbed and spirally grooved shanks increase the holding power of nails.

Nail coatings. Coating the nail shank with cement or rosin increases the holding power of a nail driven into the lighter woods such as the softer pines. The use of a coated nail for fastening the heavier woods like hard maple, birch, or oak has practically no advantage over the use of an uncoated nail.

Nail points. Generally speaking, a long sharp-pointed nail will have a greater holding power than one with a short sharp point. This is particularly true for the softer woods, but with wood that has a tendency to split when nails are driven into it, a long sharp point will increase this tendency. Once the wood splits, the nail will no longer hold. A blunt point will reduce splitting, but the destruction of the fibers when it is driven reduces the holding power. A blunt tapered nail will not split the wood so readily as a long or short sharply pointed nail, and will not have the same destructive effect on the wood fibers.

The shank. The holding power of a nail varies with the area of the shank in contact with the wood; therefore the choice of the proper size is important. Nails driven into softer woods should be long enough to extend at least two-thirds their length into the member that is receiving the point, or at least three times longer than the thickness of the outer piece. Nails driven into hard woods should be two and one-half times longer than the thickness of the outer piece. This applies to nails when driven in across the grain, but when driving nails into the end or parallel to the grain the length of the shank should be from 4 to 5 times the thickness of the outer piece.

Nailing practice. Good nailing practice consists of selecting the proper type, size, and number of nails to be used, and then arranging the pieces to be joined in such a manner as to obtain the greatest holding power from the nails. The characteristics of the types and sizes in relationship to their effect on the wood have already been discussed.

The number of nails that should be used will depend on their placement. Although great consideration may be given to the proper size and type of nail, if the nails are not carefully placed the wood may be split or the joint will be weak. Careful placement permits the use of as many as possible without splitting the wood. Nails placed close together in a line following the grain act as a series of wedges, and result in splitting the wood. The same number of nails placed just as close but slightly staggered can be driven in without any danger of this occurring. (See Fig. 4-74.)

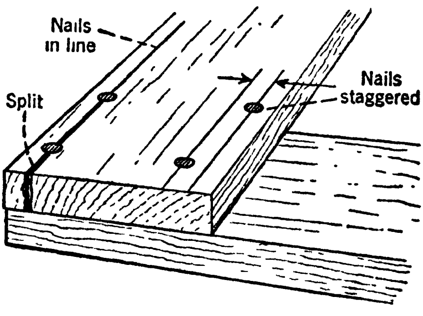


FIG. 4-74. Staggering nails lessens the possibility of splitting.

If it should be necessary to locate nails in a straight line following the grain, splitting can be prevented by spacing them a greater distance apart. Nails should never be placed any closer to an end, edge, or face than is necessary. Nails have a tendency to follow the grain of the wood, and since a piece of wood with a straight grain is rarely obtained, a great deal of difficulty is often encountered when trying to drive a nail straight. This can be overcome by boring a hole smaller than the diameter of the nail that is to be driven. It is done with a twist drill or drill point as described on pages 15–16.

In order to avoid driving nails directly into end grain, a method known as toenailing is used. (See Fig. 4–75.) This is nothing more than driving a nail obliquely into the surface of the wood.

Nails should never be used in direct tension as shown in Figure 4–76*A*, but in lateral resistance as shown in Figure 4–76*B*. A pull on the drawer front shown in *A* is in the same direction necessary to draw the nail out. Drawer *B* has the nails driven in at right angles to the direction of force which would be exerted on the drawer front.

If the unit that is being assembled with nails is to be finished with paint, stain, or any other kind of finishing material, the nail heads should be set (driven below the surface of the wood) and covered with a filler. The use of the nail set is described on page 30.

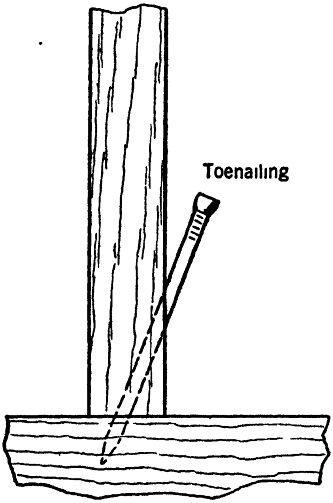


FIG. 4–75. Toenailing avoids driving nails directly into end grain.

With few exceptions, it is poor nailing practice to use a nail of such length that it will pass through both members being fastened together and project beyond the opposite side. When this is necessary, the point of the projecting end should be bent over. This process is known as *clinching.*

A nail should be clinched across the grain by striking it on the side. It should be done with the head of the nail resting on a metal surface so that there will be no danger of driving the nail back. Nails clinched with the grain have a tendency to split the wood.

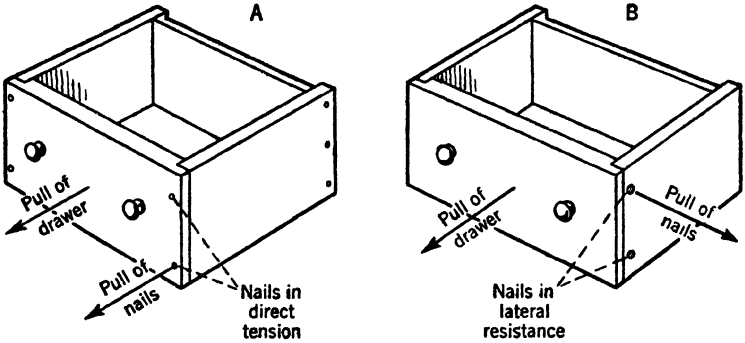


FIG. 4–76. Incorrect way of using nails (*A*) and correct way (*B*).

2. SCREWS

Screws have greater holding power than nails, and because of this fact their use is preferred. They require considerably more time and effort to apply, but their neater appearance, and the ease with which they can be removed without damaging the wood in any way, make them one of the best fastening devices available to the woodworker. (See Fig. 4–77.)

FIG. 4–77. Using a thread gage to determine the number of threads per inch on a screw.

Wood screws. Wood screws are classified according to the shape of the head, the material of which the screw is made, and the finish. (See Fig. 4–78.) The most common head shapes are flat, round, and oval. (See Fig. 4–79.) Screws are made of steel or brass; and the finish may be natural or plated.

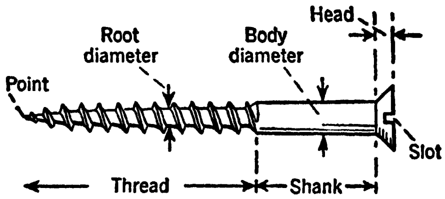


FIG. 4–78. A wood screw.

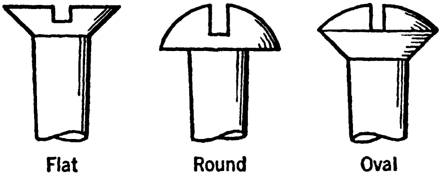


FIG. 4–79. Most common head shapes of wood screws.

The size of screws is indicated by length and diameter of the shank. The length of a screw is determined by the part that actually goes into the wood, and is measured in inches. They are manufactured in lengths of $\frac{1}{4}''$ to 5″. The diameter of the shank is designated in numbers of the American screw gage. The following table shows the gage sizes and their equivalents in inches.

Gage	Inches	Gage	Inches
0	.0578	11	.2026
1	.0710	12	.2158
2	.0842	13	.2289
3	.0973	14	.2421
4	.1105	15	.2552
5	.1236	16	.2684
6	.1368	17	.2816
7	.1500	18	.2947
8	.1631	20	.3210
9	.1763	22	.3474
10	.1894	24	.3737

Choice of sizes. When fastening two pieces of wood together with screws, the choice of the proper length screw is important to obtain the maximum holding power. The length has a direct bearing on the diameter of the shank. Screws are made in definite shank diameters for specified lengths, the most common of which are shown in Table 7 in Appendix A.

A wood screw should penetrate the second member (the one to which the first member is being attached) to a depth 7 times the shank diameter. As shown in Figure 4–80, if a piece of lumber

½″ thick is to be joined to a second member and a #5 screw is to be used, it should be 7 times longer than the diameter, plus ½″ which is taken up by the thickness of the first member through which the screw must pass. A #6 screw measures .1368″ and 7 times this would be .9576″. To this is added the ½″, bringing the total up to 1.457″ or about 1½″.

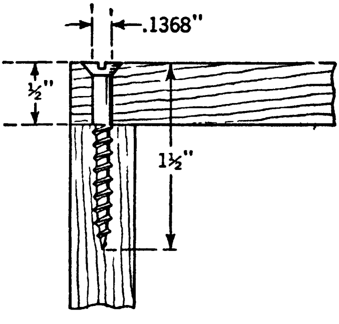


FIG. 4-80. Correct penetration of a wood screw.

Sometimes the construction of the piece is such that it is impossible to use a screw of the desired length. Then the difference can be made up by the use of several screws placed closer together, provided of course that they penetrate the second member sufficiently. It must be kept in mind that the screws should be so located as not to split the wood.

Preparing stock. When using screws, the stock must be prepared by boring a hole through the first member large enough for the shank of the screw to pass through. This is known as a clearance hole. A small hole should be bored in the second member which is to receive the threaded portion of the screw. This is called a *pilot hole.* (See Fig. 4-81.) The size of the clearance hole is determined by the shank diameter or gage number of the screw, while the pilot-hole size is based on the root diameter. (See Fig. 4-78.) The pilot holes in hardwoods should be larger in diameter than those bored in soft-

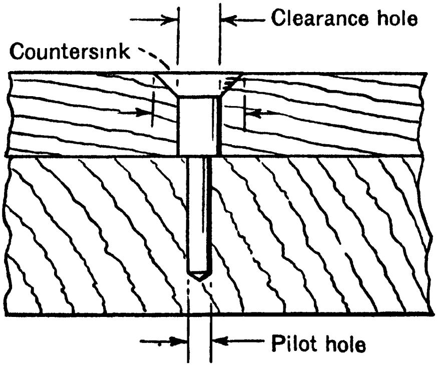


FIG. 4-81. A pilot hole.

woods. Table 11 in Appendix A shows the clearance and pilot-hole sizes for screws of various gages.

Clearance holes that are to take a flathead or oval-head screw should be countersunk. (See Fig. 4-83.) This is done with a countersink as described on pages 169-170.

When it is necessary to set the head of a screw below the surface (so as to increase the depth of penetration into the second member or to conceal the head), an operation known as *counterboring* is employed. This involves boring a hole larger than the diameter of the screw head. The diameter of a counterbored hole for screws of various gages is given in Table 11 in Appendix A. The location of the screwhole is established, and the counterbore bit is used to bore the large hole to the required depth. The clearance hole is then bored through the stock, placing the point of the clearance drill in the center mark left by the counterbore bit. (See Fig. 4-82.) A screw that is driven into a counterbored hole can be concealed by setting a wood plug in the hole. (See Fig. 4-83.) The plug may be of the prefabricated type (*A*) or the flush type (*B*). The flush-type plug is made with a *plug cutter*. The plug cutter is used in a brace in the same manner as a bit. The plugs, as they are cut, have tapered sides; when placing them in the holes, the

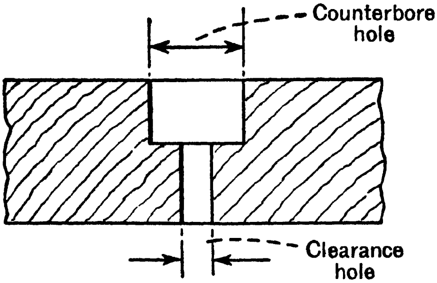


FIG. 4-82. Results of counterboring.

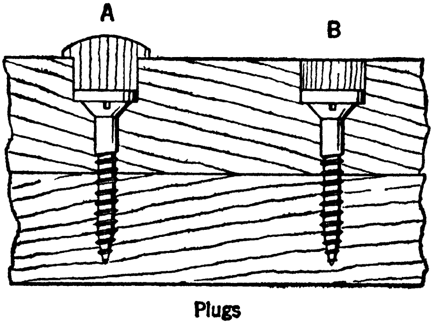


FIG. 4-83. Concealing a screw with a wood plug.

smooth face should be down. The plug is glued in the hole, and dressed flush with the surface after the glue has set. When setting in a plug, the grain of the plug should follow the grain of the stock into which it is set. (See Fig. 4–84.)

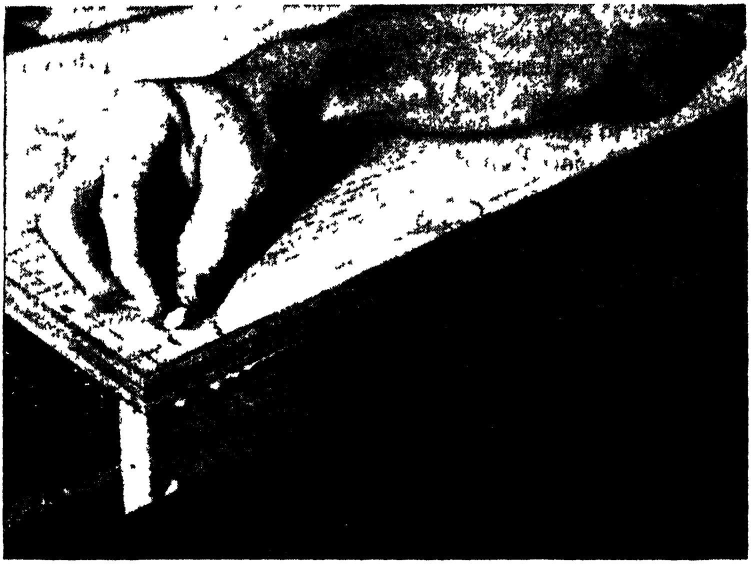


FIG 4-84. Putting a wood plug over a screw

When driving screws into hardwood, it is advisable to lubricate the thread Soap or wax, both good lubricants for the purpose, can be applied to the thread by placing the screw on the soap or wax and drawing it across the surface. Sufficient soap or wax will adhere to the thread to act as a lubricant. This will reduce friction, making the screw easier to drive, and eliminate the danger of the screw's breaking inside the wood. Never use oil, which may expand the wood fibers so greatly that the screw cannot turn.

Use of the ratchet brace and screwdriver bit. When it is necessary to drive a number of screws, the ratchet brace and screwdriver bit should be used. Because of the leverage that can be obtained with a brace, it is easier to use the screwdriver bit with it.

The tip of the screwdriver bit must fit the screw slot, as described on page 101. It is placed in the ratchet brace in the same manner as any other square-tanged bit. When using this combination of tools, be sure to place the screwdriver bit in the slot and hold the brace so as to form a straight line from the knob of the brace through the axis of the screw.

Pressure to hold the screwdriver bit in the screw slot is exerted by one hand placed on the knob of the brace. This hand must also steady the brace. The revolving of the brace, by the hand placed on the handle, does the driving or removing of the screw. The brace is revolved in a clockwise direction to drive the screw, and counterclockwise to remove it.

The ratchet attachment on the brace permits the movement of the chuck and screwdriver bit in one direction only. When the ratchet is engaged, it is possible to remove the bit if the handle of the brace is moved in one direction, but if the movement is reversed the screwdriver bit will not turn. This is useful when driving screws into locations that will not permit the full sweep of the brace, for a series of part-turns and reverses will drive the screw.

Lag screws. Lag screws are heavy-duty wood screws with square heads. (See Fig. 4-85.) They come in lengths ranging from 1″ to 16″ and have shank diameters ranging from $\frac{1}{4}$″ to 1″. They are driven by a wrench rather than a screwdriver. The wood into which they are driven is prepared in the same manner as that described for wood screws. When using lag screws, always place a washer under the head.

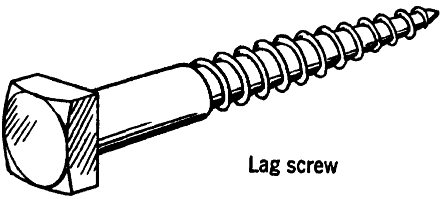


FIG. 4-85. A heavy-duty wood screw.

3. BOLTS

A bolt is an iron or steel rod, with sides parallel throughout its length, with a head at one end and a thread cut part way along its length from the other end. The thread is cut to receive a nut. Bolts are used when the holding power of nails or screws would not be sufficient. Unlike nails and screws, bolts do not have to depend on friction and cell structure for their holding power, for the force which holds the stock together is positive. The bolts most commonly used by the woodworker are stove bolts and carriage bolts. (See Fig. 4–86.)

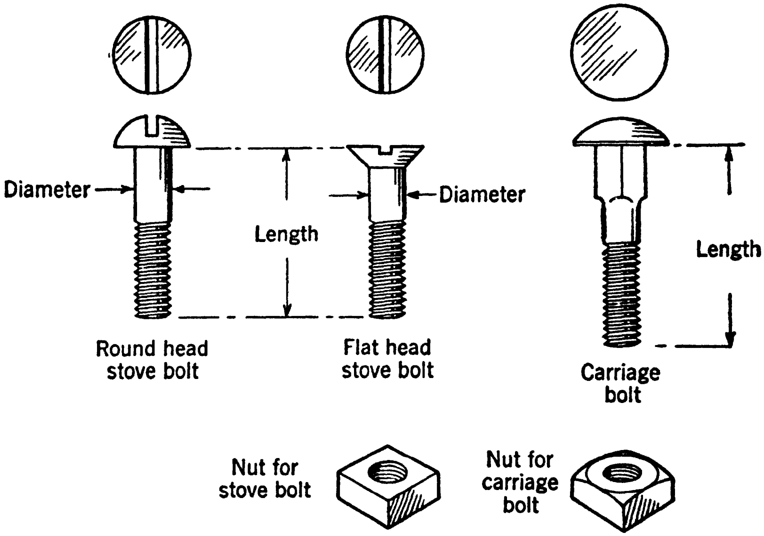


FIG. 4–86. Bolts most commonly used by woodworkers.

Stove bolts. Stove bolts, like wood screws, are made with round or flat heads, slotted for a screwdriver. They range in sizes from $\frac{3}{8}''$ to $6''$ in length and from $\frac{1}{8}''$ to $\frac{1}{2}''$ in diameter. The length and diameter of stove bolts are measured as shown in Figure 4–79.

When using stove bolts, a clearance hole must be bored through both members that are to be joined. (See Fig. 4–87.) The diameter of the bit used to bore the hole should be equivalent to that of the bolt. When a flathead stove bolt is used, the clearance hole must be countersunk. (See Fig. 4–88.)

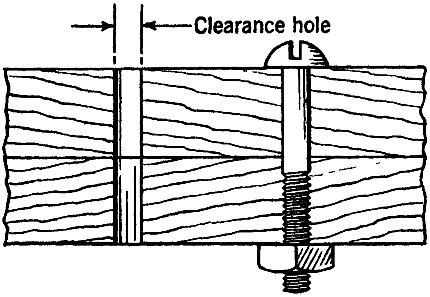


FIG. 4–87. Use of stove bolts.

A stove bolt should be long enough to allow at least $\frac{3}{8}''$ of the threaded portion to project beyond the hole. The nut is screwed on the projecting end of the bolt, then tightened by the use of a screwdriver placed in the slotted head. If it should be necessary to hold the nut securely while it is being tightened, a wrench of the proper size should be used.

Carriage bolts. The carriage bolt is one form of bolt designed specifically for wood. The square section, under the head, is forced into the wood, preventing the bolt from turning as the nut is tightened. (See Fig. 4–89.) Carriage bolts range from $\frac{3}{4}''$ to $20''$ in length and from $\frac{3}{16}''$ to $\frac{3}{4}''$ in diameter. The length and diameter are measured as shown in Figure 4–89.

The use of a carriage bolt requires the boring of a clearance hole through both members. The diameter of the hole should be equivalent to that of the bolt. The length of the bolt should be great enough to allow at least $\frac{5}{8}''$ to project beyond the members that are being joined together.

When applying the bolt, it is placed in the hole and driven in with a few hammer blows on the head to force the square section into the wood. A washer is placed over the projecting end of the bolt before applying the nut. (See Fig. 4–89.) The washer should have a hole of the same diameter as the bolt. The nut is tightened with a wrench.

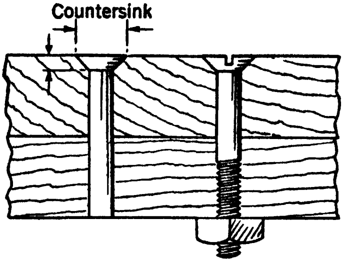


FIG. 4–88. A flathead stove bolt.

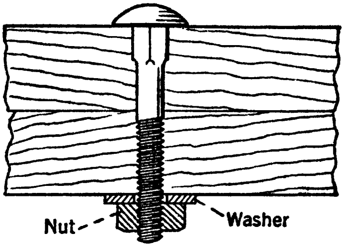


FIG. 4–89. A carriage bolt.

4. GLUE

Glue, an adhesive preparation, is used to join or fasten one piece of wood to another. For successful gluing, the two surfaces should be in complete contact over the entire joint area, with a continuous film of glue between them; the film should be unbroken and free from air bubbles or foreign particles. The strength of a glue joint depends on several factors: the wood, the glue, the gluing conditions, the type of joint, and the protection given to the assembled unit when placed in service.

Dense woods, hardwoods, and the heartwood of most species are more difficult to glue than the woods that are light in weight, the softwoods and the sapwood. With the first group, the gluing conditions must be carefully controlled and rigidly adhered to; with the second group, moderate care in the gluing operation will produce successful joints. Wood that is used for furniture or interior work should have a moisture content of from 5 to 6 per cent for satisfactory gluing. Lumber for outside use can be glued successfully if its moisture content is about 12 per cent.

Glues most commonly used in making joints in wood are animal glue, casein glue, liquid glue, and waterproof resinous glue. These four types differ in some respects, such as consistency, rate of setting, strength, and water resistance.

The consistency of animal glue is variable from thin to very thick, depending on the changes in temperature. Its rate of setting is rapid. The strength of the glue is very high when gluing conditions are ideal. Its resistance to water is low, and it should therefore never be used for outside work or on work that may be exposed to dampness or moisture.

Liquid glue varies in consistency from thin to medium. It does not set as rapidly as animal glue. The strength is high, but its resistance to water is low. Casein glue varies from medium to thick in consistency. It has a rapid rate of setting, its strength is very high, and its water resistance is rather high.

The conditions under which glue can be applied are extremely variable, and depend on the properties of the glue, the method of preparing it, the quantity of glue that is spread, and the length of time elapsing between spreading the glue and applying the clamps. The clamps are used to squeeze the glue out into a thin continuous film and to hold the pieces in close contact with one another until the glue has set. The consistency of the glue controls the amount of pressure required by the clamps. A thin glue should have a light pressure applied by the clamps, but a thick glue requires a heavy pressure. The elapsed time between the spreading of the glue and the application of the clamps will depend on the rate of setting. The more rapidly a glue sets, the shorter must be the elapsed time. A glue that requires heat in its preparation, such as animal glue, should be applied in a warm room because it chills and thickens very rapidly. Casein and liquid glue, which are applied cold, do not require a controlled room temperature. The clamps should be left on the work until the glue has set and there is no danger of the joint's opening. This takes from 4 to 8 hours, depending on the thickness of the stock and its ability to absorb the moisture present in the glue.

Satisfactory glue joints can be made only between edge-grain surfaces. (See Fig. 4-32.) It is impossible to produce a strong joint by gluing two pieces end-to-end or end-to-edge. This difficulty is overcome by the use of a cut joint, such as the lap joint and the mortise-and-tenon joint. (See Figs. 4-34 and 4-65.)

Any moisture changes in the wood after it has been joined by glue affect the strength of the joint. Animal and liquid glues, which have very little water resistance, should never be used when there is the slightest chance that the pieces which are being joined will be exposed to dampness or moisture. Casein glue, which is fairly high in water resistance, will resist the many changes in moisture content; but when exposed to these changes over an extended period, it will break down. In order to protect the glued joint after it has been made, the outer surfaces of the wood should be coated with a sealer, such as paint or varnish. This closes the pores of the wood, preventing any moisture from entering.

Preparation of animal glue. Animal glue must be prepared in a double boiler. (This consists of a small pot in which the glue is mixed, held in a larger one with water in it.) Animal glue comes in the form of cake, flake, and powder. The cake, if used, must be broken into small pieces. The glue is mixed with water in the proportions recommended by the manufacturer. The mixture should be thoroughly stirred to allow a uniform absorption of water and to prevent the formation of lumps. The mixture should stand several hours until the glue is thoroughly soaked and softened. When the mixture is ready, it is heated over a water bath at a temperature no higher than 150° F. This is done by pouring water in the larger pot of the double boiler and placing the smaller one in it. When the glue is warmed, it is applied with a brush to the surfaces to be joined. When preparing animal glue, mix sufficient for the day's work only. The reheating of glue reduces its strength and results in weak joints. The glue pot should be cleaned after the day's work, for glue is a breeding place for bacteria which decompose and weaken it.

Liquid glue. Liquid glue requires no preparation, for it comes ready for use.

Casein glue. Casein glue is obtained in powder form, and prepared by mixing it with water. It contains alkalies which corrode most metals; therefore it should be prepared in a glass or porcelain container and mixed with a nonmetallic mixer. The glue-water ratio is determined from the manufacturer's recommendation and should be strictly adhered to. The working period of a casein-glue mixture is no more than several hours, after which it begins to set. For this reason it should be prepared in small quantities.

Synthetic-resin glue. The most modern of all glues is the synthetic-resin glue made of chemicals. There are two types, the urea-aldehyde combinations and the phenol-aldehyde combinations. They are obtainable in powder form (to be mixed with water), in liquid form, and in a dry film form; the latter two are ready for use.

The urea-aldehyde adhesives in liquid form require the addition of a hardener, or *catalyst*, just before using. This catalyst is supplied with the adhesive, and is added to it just before using. When preparing a liquid urea-aldehyde glue by adding the catalyst, prepare only enough for immediate requirements; once the hardener is mixed, the adhesive begins to set, or harden. Some of the urea-aldehyde adhesives in powder form have the catalyst already added. When this type is prepared with water, the action of the catalyst begins. For this reason, urea-aldehyde adhesives in powder form should be kept in closed containers to keep out moisture.

In general, the phenol-aldehyde adhesives require simultaneous application of heat and pressure. This operation is known as *hot pressing*. A joint made with such an adhesive properly applied has a very high resistance to moisture. The majority of urea-aldehyde adhesives also require hot pressing, although the temperatures required are generally lower. There are some urea-aldehydes that can be spread and pressed at room temperature. Like the phenol resins, the urea resins, when prepared and applied as directed by the manufacturer, are highly water-resistant.

Applying clamps. The period between application of glue and need for pressure exerted by clamps is relatively short; therefore, you should check and arrange the clamps to receive the pieces before gluing is begun. If there is any danger of the clamps' marring the wood, place a piece of stock between them for protection.

5. DOWELS

Dowels are cylinders of solid wood used to reinforce joints. (See Fig. 4–90.) They are usually made of close-grained hardwood, such as birch or maple. The size of a dowel is determined by its diameter; sizes range from $\frac{3}{16}''$ to 1″. Dowel lengths are a standard 36″. Shorter lengths, ready for use, can also be obtained, each with the ends chamfered and a straight or spiral groove cut along its length. The purpose of the groove is to permit the excess glue and air to escape from the hole in which the dowel is placed when assembling the work. The diameter of a dowel should be about half the thickness of the smallest member being joined; the length of the dowel should be four times the diameter. (See Fig. 4–91.)

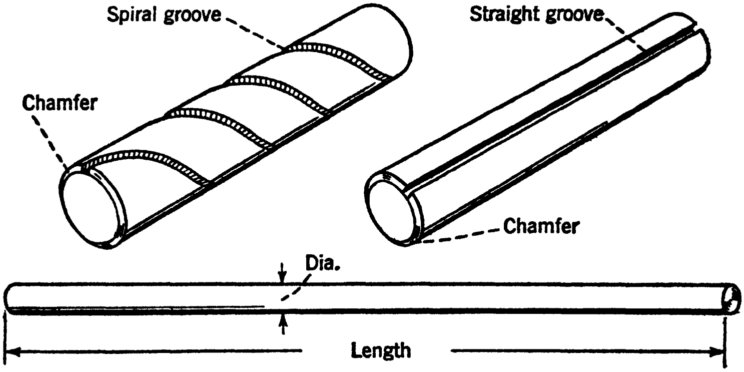


FIG. 4-90. Dowels.

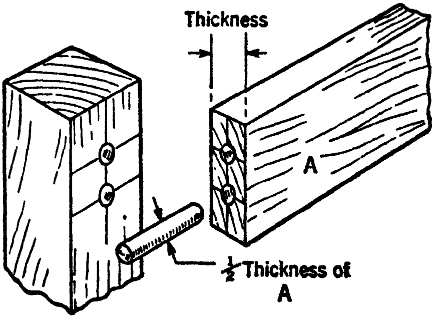


FIG. 4–91. Diameter and length of a dowel.

Laying out dowel holes. When using dowels to reinforce edge-to-edge butt joints, such as would be required to make up a wide panel, the stock should be prepared as outlined for the butt joint on page 172. In order to line up dowel holes, they must be located simultaneously on both pieces. The boards are placed on the bench with the butting edges in their relative position and marked as shown in Figure 4–92. They are next placed face to face, with the edges which are to be joined flush with one another and held together by means of handscrews.

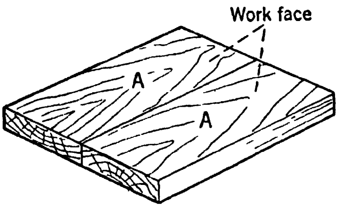


Fig. 4–92. Placement of boards in laying out dowel holes.

The number of dowels to be used must be determined before their location can be established. The dowels should be placed from 6″ to 8″ apart, depending on the length of the edge; but in any case no less than two dowels should be used nor should they be placed any closer than 1″ from either end. When the number of dowels to be used has been decided, the laying out of their location should be started, from the center rather than the end. A center line is squared across both edges, using a trysquare; then from this center line the dowel-hole locations are marked. (See Fig. 4–93.) The handscrews are removed and the marking gage is set for half the thickness of the stock. A gage line is scribed across the dowel-hole locations, keeping the head of the gage against the work face. (See Fig. 4–94.)

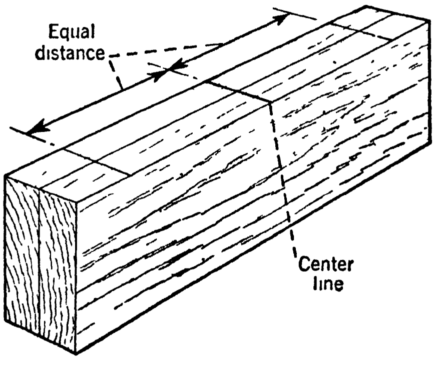


Fig. 4–93. Dowel-hole locations are marked from a center line.

Boring dowel holes. Dowel holes are bored with an auger bit of the same size as the dowel to be used. The depth of the hole should be $\frac{1}{16}''$ more than half the length of the dowel. A bit gage such as that of Figure 4–95 is extremely helpful when boring holes to a required depth. When a bit gage is placed on a bit, it should be slipped on from the tang end. When the gage is set to bore a hole of a predetermined depth, the measurement should be made from the lip of the bit to the end of the gage. It is important to keep the bit square to the surface into which the hole is being bored; otherwise the dowels will not line up with the dowel holes when the two pieces are assembled.

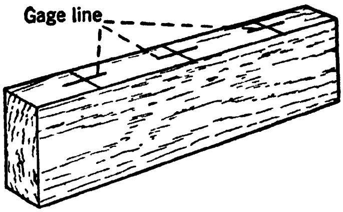


Fig. 4–94. Gage lines across the dowel-hole locations.

The laying out of an end-to-edge butt joint is done in the same manner, except that the holes are located and bored in the edge of one piece and the end of the other. (See Fig. 4–91.) A minimum of two dowels should be used, placed no closer to the edges of the wood than twice the dowel diameter.

Dowels are cut to the required length with a backsaw. The ends should be chamfered and a saw kerf made along the dowel. (See Fig. 4–95.) Glue is used to hold a dowel joint together.

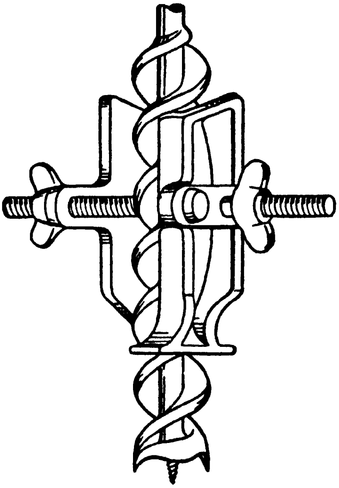


Fig. 4–95. A bit gage.

F. FINISHING

Wood finishing is the process of removing all tool marks from the wood by the means of a cabinet scraper and sandpaper, and applying a protective coating to the surface. In most cases, the scraping and sandpapering of the work can be done after it is assembled; but surfaces that would be difficult to work on after assembly, such as the inside of a drawer, should be finished before assembly.

1. SCRAPING

In woodworking scraping is the process of smoothing a wood surface by removing material in very thin shavings. A cabinet scraper is generally used for this purpose. Scraping may follow coarse planing, to remove irregularities left by the plane. When a surface has changes in grain direction, scraping should replace planing, which would tear or split the wood fibers.

Veneers which are no more than $\frac{1}{28}''$ in thickness should never be planed on the surface, as this removes too much of the material. The scraper should be used, for the shaving produced by this tool is considerably thinner than that produced by the plane.

The refinishing of flat surfaces of furniture can best be done by scraping. After the greater part of the old finish has been removed with a varnish remover, the cabinet scraper is used to complete the work of preparing the surfaces for the new finish. The cabinet scraper and its use were described on pages 64–65.

2. SANDING

Sanding is the process of removing all tool marks or other irregularities to produce a smooth even surface on the wood. Sandpaper is generally used for this purpose. Sandpaper is a coated abrasive made of finely ground flint quartz or garnet crystals cemented to heavy paper or cloth. Flint-quartz paper can be obtained in grades ranging from No. 3½ to No. 5/0; garnet paper is made in grades from No. 4½ to No. 10/0. The grading of the abrasive is based on the size of the crystals; No. 4½ is the coarsest, and No. 10/0 is the finest.

The first sanding should be done with #1 to #½ sandpaper, depending on the amount of wood that must be removed to eliminate tool marks. This is followed by the use of a #0 or 2/0 sandpaper.

Sandpaper is made in rolls and in 9″ × 11″ sheets. It can be cut by folding it over a sharp corner of the bench and tearing it along the fold line; under no condition should any cutting tool be used to cut sandpaper. The most convenient size for a piece of sandpaper is 4½″ × 5½″, which can be obtained by cutting a full-size sheet into four parts.

For sanding, the sandpaper must be stretched over a block. The block should be 3″ wide, 4″ long, and at least ¾″ thick. It should be made of cork or of wood with a thin layer of cork glued to one face. (See Fig. 4–96.) The purpose of the block is to prevent the rounding of corners or the cutting of grooves in the surface of the work being sanded.

The stock to be sandpapered should be held securely in the vise or to the bench top by means of a hand screw. The sandpaper block is grasped in both hands, with the fingers on one edge and the thumbs on the other. The surface should be sanded *parallel* to the grain in order to avoid scratches or marks showing through the finish. When sanding concave surfaces the sandpaper should be wrapped around a dowel or a sandpaper block shaped to fit the curve.

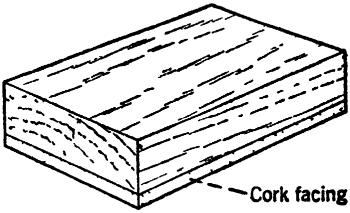


FIG. 4–96 A block for sandpaper.

G. WOOD PRESERVATION

1. PURPOSE OF PAINTS

Paint has many purposes, but the most important one is to protect wood from moisture, which causes decay, and from changes in moisture content, which cause joints to open, boards to warp, and faint cracks to appear on the surface of the wood. Paint is also used to provide a surface that cannot be discolored, spotted, or stained by dirt. Since paint is a material that can be spread to form a thin hard film, resistant to moisture, and capable of adhering to a wood surface, it is ideally suited to this purpose. In protecting wood by sealing it from decay, it prolongs the life of the article made of wood. Paint also improves the appearance of a structure or a piece of furniture by its various shades and colors.

Paint as camouflage. In time of war, camouflage of military objectives is highly important. Camouflage serves to (1) *conceal* an object, (2) *disguise* an object so that it appears to be something else, or (3) *blend* an object with its surroundings. Concealing an object is done by covering it so that it cannot be seen by an observer. Armed forces use shams which are very much like theatrical "props" to conceal gun emplacements, observation posts, and other military objects. Although sunproof-dyed fabrics are the most satisfactory materials, water-painted materials are suitable and often more available. Oil paints should not be used, however, since they tend to cause spontaneous combustion when the materials are stored.

To disguise them so they will appear to be something else, military objectives are usually made to look like something nonmilitary. For example, large factories are painted so that at a distance they appear to be nothing more than a series of houses. Trees, shrubbery, small roofs, and "blank" areas are painted on the walls of the large buildings.

One of the most interesting phases of camouflage concerns aerial observation. Early in World War II the Germans had successfully painted roofs of warehouses and factories to resemble side streets and countryside. Bombardiers could not be sure where to drop bombs. But aerial photographers, hoping to record scenes of damage to military objectives, took pictures. When these were developed they showed the use of camouflage. Aerial photography was then used both to detect the camouflage of enemy objectives and to check the success of camouflage at home.

To make an object blend with its surroundings, painters give it similar coloring. During wartime most ships are painted a color such as battleship gray, which blends with the sea and the sky. Airplanes are frequently painted a metallic sky blue on the underside and an earthy color on the upperside, thus making them less visible from below when they are in the air and from above when on the ground. Uniforms are dyed to match the terrain: green, slate blue, khaki, and so on. For many years soldiers were taught to cover their faces and hands, and bright objects such as buttons and bayonets, with dust or mud to make them less conspicuous. Now they are taught how to use paints, which are much more satisfactory for the purpose. First a tan undercoating of paint is applied to prevent reflection; then irregular streaks and splotches of olive-drab are added to make the skin blend with the vegetation and to break up the characteristic pattern of features, which make it recognizable as a face.

Paints can be divided into three main groups: exterior paints, interior paints, and enamels. Exterior paints are prepared to withstand the effects of weather. Interior paints protect surfaces that will not be exposed to the elements, such as interior trim and cabinetwork. Enamels are for interior and exterior work.

2. CARE OF BRUSHES

With the proper care, brushes used to apply finishing material such as stain, paint, lacquer, varnish, or shellac will last indefinitely. The first things to learn about the care of brushes are their types, shapes, and purposes. There are two types of brushes, chiseled and square-trimmed. These terms apply to the shape of the ends of the bristles. (See Fig. 4-97.) The *chiseled brush* is used for applying finishing materials such as enamel, varnish, shellac, and lacquer. The *square-trimmed brush* is used to apply paint which must be *brushed* on. There are three shapes of brushes:

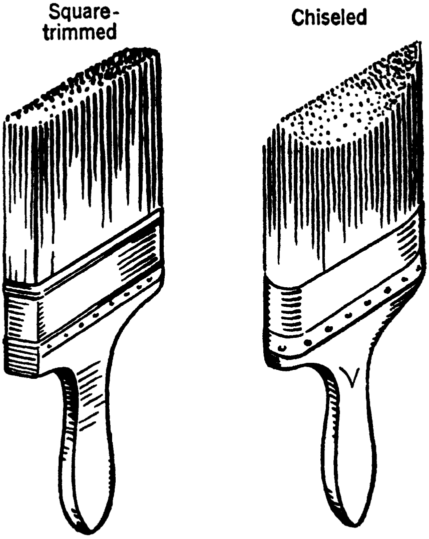


FIG. 4-97. Two types of flat brushes.

the flat brush, the round brush, and the oval brush. (See Figs. 4–97 and 4–98.) Any one of these shapes may have the bristles square-trimmed or chiseled, depending on the finishing material for which they are used. Oval and round brushes, because of the large number of bristles concentrated in a comparatively small area, permit the flowing on or brushing of a greater amount of finishing material than a flat brush of the same width. Brushes of this shape are useful for painting sash or other narrow surfaces. It is good practice to have a different brush for each kind of finishing material and to clean it immediately after it has been used.

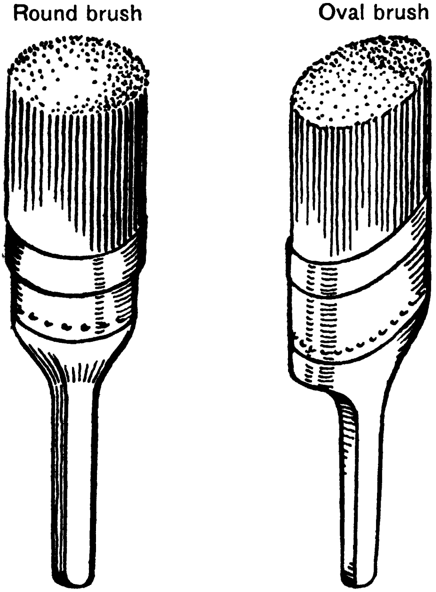


FIG. 4–98. Round and oval brushes.

A brush must be cleaned with the solvent of the finishing material for which the brush was used. Turpentine or benzine should be used to wash a brush that was used on any material other than lacquer, shellac, spirit stain, and water paints or stains. A brush used for lacquer must be cleaned with a lacquer thinner. It is advisable to use a lacquer thinner made by the manufacturer of the lacquer used. Brushes used for shellac and spirit-stain should be cleaned in alcohol; brushes used for water paints and water stains should be cleaned with water.

When cleaning a brush, it is best to have two containers of the solvent. Use one to remove the greater part of the finishing material from the brush, and the other to complete the cleaning. During the washing, work your fingers through the bristles to loosen any material that may be lodged there. After each wash, wipe out as much of the liquid as possible by drawing it across the edge of the container; then shake out whatever remains.

Paint and varnish brushes which are to be used for two or more days need not be cleaned each day provided they are stored in brush keepers after using them. A brush keeper is a container in which the brush is suspended or hung in such a manner that the bristles are immersed in liquid but do not come in contact with the bottom of the container. (See Fig. 4–99.) Brushes used for oil paints should be immersed in raw linseed oil. Varnish brushes should be kept in brush-keep varnish. Shellac, lacquer, and water-paint brushes should be cleaned immediately after each use, for these brushes cannot be stored in a brush keeper.

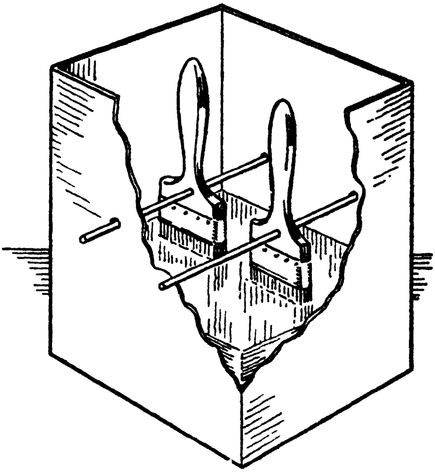


FIG. 4–99. A container for brushes.

Brushes that have been neglected, with paint and varnish hardened on them, can never be put back into first-class condition. Such a brush can be cleaned sufficiently to work on large rough surfaces, but it can never be depended on to produce a fine finish. There are a number of brush-cleaning solutions for reclaiming hard brushes. If any of these are used, the manufacturer's directions should be followed. Varnish and paint removers are also helpful. When reclaiming old brushes, suspend the brush in the solution until the material adhering to the bristles begins to soften. Remove the brush and scrape out the old paint with a putty knife or steel comb. Wash the brush in turpentine or benzine, working the liquid through the bristles with your fingers. Be sure that the chemicals are thoroughly washed out.

After it is thoroughly clean, wrap the brush in heavy wrapping paper or several thicknesses of newspaper. This will hold the bristles in line while they are drying. Bristles that are bent or curved through neglect can often be straightened by this method.

Brushes may be stored by suspending them from the handle or by laying them down flat; but in any case care must be taken not to change the arrangement of the bristles or place them so that there would be any weight on the bristles.

3. COMPOSITION OF PAINTS

Water paints. Calcimine is a water paint made of whiting (chalk) and glue, mixed with water. It is used for decorating and protecting interior walls and ceilings. It can be tinted any shade by the addition of colors soluble in water. Since calcimine is water-soluble after (as well as before) it has been applied and has dried, it should be used only where there is no danger of moisture coming in contact with it.

Casein paint is a form of water paint made of casein and pigment, mixed with water. It is used for interior work, decorating and protecting walls, ceilings, and woodwork. It dries hard and will not powder or brush off as readily as calcimine. Since casein is used as the base in preparing this form of paint, it is more resistant to water than calcimine.

Whitewash is a mixture of slaked lime and water. It is used for whitening exterior structures. It can be used with equal success on wood, stone, concrete, and metal. While it does not form as permanent a protective coat as an exterior paint, it does afford some protection from the elements to the surface on which it is applied. Wooden buildings have been known to stand the ravages of time with frequent applications of whitewash.

Cement paint. There are a number of paints designed specifically to protect cement and concrete surfaces, but any oil paint, properly applied, will do the job. When painting cement two points must be kept in mind: the destructive action of paint on the cement and the destructive action of cement on paint.

All nondrying oils, such as raw linseed oil, have a tendency to disintegrate cement. The disintegration forms a powder which prevents paint from adhering. When preparing an oil paint for cement work, *boiled* linseed oil should be used rather than *raw* linseed oil. The priming or first coat should be thinned with turpentine, and the amount of turpentine used should be decreased with each succeeding coat. Sufficient time should be allowed of course for each coat to dry thoroughly before applying the next coat.

The destructive action of cement on paint can be reduced to a minimum. Most often the trouble is caused by applying paint before the cement is dry. A cement wall or floor should be allowed to stand at least one summer so that it can dry thoroughly. Too, there is a considerable amount of alkali in cement that must be counteracted before you apply paint. The surface to be painted should be washed with a solution of muriatic acid, using 1 part of acid to 11½ parts of clean water. This can be applied with a brush, but precautions should be taken to protect the hands. The surface should then be washed with clean water to remove the acid solution.

Oil paints. Oil paints are composed of a *base* of white lead or zinc white; a *pigment*, which is the coloring material; and a *vehicle*, which may be linseed oil or varnish. A material known as a *drier* is often added to a paint mixture to speed up the drying process. If the mixture of basic materials is too heavy to brush well, add a volatile thinner such as turpentine. The turpentine thins the mixture to a consistency that is workable, and evaporates after the paint is spread. Varnish is often added to paint mixtures to produce a gloss.

While most oil paints contain the same basic ingredients, the proportions will vary, depending on their use. Unpainted wood should be given three coats of paint: a priming coat, a second coat, and a finish coat. A formula, suitable for mixing an outside paint, is given on the following page.

MATERIALS	QUANTITY	PRIMING COAT	SECOND COAT	FINISH COAT
White lead	lb.	100	100	100
Linseed oil	gal.	4	1½	3¼
Turpentine	gal.	2	1½	
Drier	pt.	1	1	1
Gallons of paint		9⅜	6⅜	6⅝
Sq. ft. covered by 1 gal. (1 coat)		600	700	700

An interior paint for wood can be prepared by using the following formulas:

MATERIALS	QUANTITY	PRIMING COAT	SECOND COAT	FINISH COAT
White lead	lb.	100	100	100
Linseed oil	gal.	3		
Turpentine	gal.	2	1½	1½
Drier	pt.	1	½	¼
Varnish	gal.		¾	1½
Gallons of paint		8⅜	5½	6¼
Sq. ft. covered by 1 gal. (1 coat)		600	700	800

White-lead paints can be colored any shade or tint by using colors ground in oil. When coloring paint, always add small quantities at a time and stir them in completely to avoid too much color. If a tint is too dark, the only way it can be made lighter is by adding more white paint.

Mixing colors. The basic colors from which the hues can be obtained are red, blue, and yellow. (See Fig. 4–100.) Red and yellow produce yellow-red or orange. Yellow and blue produce blue-green, green-yellow, or green, depending on the proportions. Purple, red-purple, and blue-purple are produced by mixing blue and red.

When the three basic colors, or any two complementary colors (such as red and blue-green, yellow and purple-blue, green and red-purple, blue and yellow-red, or purple and green-yellow) are combined, a neutral gray is produced. As the quantity of one of the complementary colors is increased, this neutral gray changes

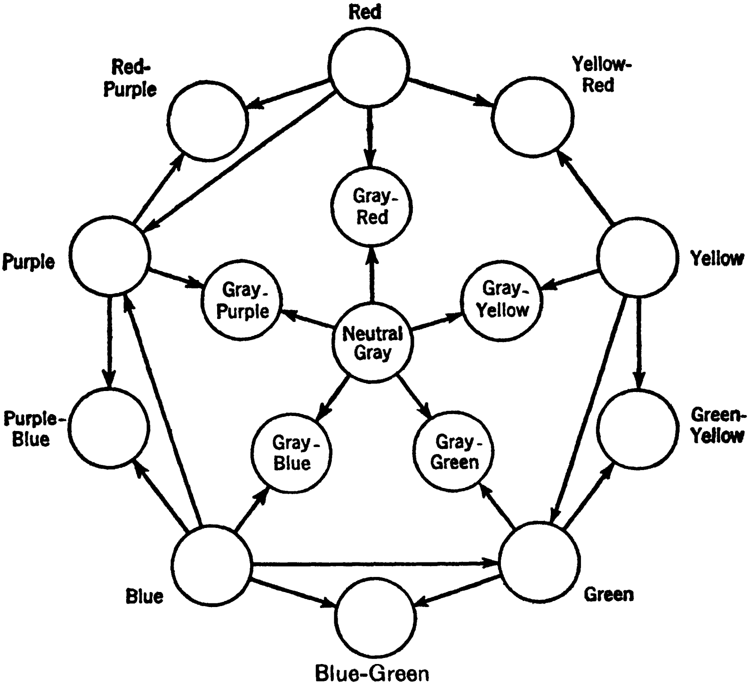


FIG. 4–100. Spectral chart.

to a drab. For example, if green and red-purple are mixed in the proper proportions a neutral gray is produced. If more green is added the result will be a gray-green or drab green. On the other hand, if more red-purple is added the result will be a drab red-purple.

The value of the principal and intermediate hues, as well as the grays or drabs produced by mixing complementary colors, can be changed by the addition of black or white. If we take the principal hue red and add white to it we obtain a light red or pink. If black is added to red, the result will be a dark red or maroon. A red-gray can also be varied in value by adding white to make it a light red-gray or a black to make it a dark red-gray.

Matching colors. In order to match colors, it is necessary to prepare a sample by mixing the various colored pigments and comparing it with the sample that is to be matched. The information given for the mixing of colors will aid in obtaining the various hues, color values, and intensities. It will take a little practice and experience to obtain the required results. The quantity of each color used to match a given sample must be recorded, and the same proportions must be used when preparing sufficient paint for the work that is to be undertaken. If it is necessary to match a color that is already dry, several samples should be prepared ranging from one that is too dark to one that is too light. The rest of the samples should range between these two. The prepared samples should be placed on a piece of wood and allowed to dry. In this manner the correct color can be obtained without unnecessary delay.

4. APPLYING PAINT

The condition of the wood and the weather must be taken into consideration before attempting to paint. A surface that is damp or wet should be given time to dry out thoroughly. Paint should never be applied under extremely cold, frosty, or damp conditions. On woods such as pine and fir that contain knots and pitch pockets, a coat of shellac should be applied to seal in the pitch and prevent it from bleeding through the paint.

The brushing technique is extremely important, for it influences both the appearance of the job and the durability of the paint coating. The desirable type, shape, and size of brush must first be determined. (These were described on page 216.) Brushes come in various widths to meet the requirements of the surface that is to be finished. Large surfaces require the use of a wide brush, and small surfaces should be finished with a narrow brush.

The object of the brushing is to spread the paint so as to insure a uniform film of proper thickness. The proper thickness of the film depends on the purpose of the paint and on its brushing characteristics. For this reason, paint formulas should be followed carefully when mixing paints; and when using prepared paints, the manufacturer's recommendation for thinning should be followed. Each paint has its consistency controlled by the materials used in its preparation, and any change in this will alter the brushing characteristics.

Exterior paint should be applied freely with a brush that is fully charged. It should be brushed out well to produce a thin uniform film, brushing across the grain to spread it and finishing the surface with a few light brush strokes with the grain. Each coat should be applied in the same manner.

A flat paint should be applied with a minimum of brushing. A fairly full brush of paint is used, and the paint is spread quickly over an area two or three feet square. Light cross-strokes should be used to spread it uniformly. This procedure will keep brush-marks at a minimum.

Enamels and varnishes set quickly; therefore, as little brush work as possible should be used. They can be spread in a thin even coating by working small areas at a time.

Paint being stored should be placed in as small a container as possible. A small amount of paint in a large container permits the formation of additional useless film. Be sure paint-can rims are clear of paint before putting the cover on. See that the cover is tightly in place.

5. VARNISH

Varnish is another protective coating for wood, but it contains no pigment as paints do. It is a liquid which when spread on a surface in a thin film dries hard and transparent or semitransparent, protecting the surface of the wood from moisture and dirt. It dries by oxidation, that is, by combining with air and by the evaporation of the volatile fluid in it. It has a decorative value, increasing the brilliancy of colors over which it is applied as well as preserving them. There are varnishes which produce a high glossy finish and those which have a dull luster.

Oil varnish. Varnishes can be grouped into three classifications: oil varnish, spirit varnish, and japan varnish. Oil varnishes are solutions of gum resins and oils, with small amounts of metallic salts added to speed drying. Some gum resins used are amber (a fossilized vegetable resin), kauri (a resin from the kauri pine), Zanzibar, Pontianak, and Sierra Leone. The three latter gums derive their names from the places where they are obtained. Some oils used are linseed, tung oil (china wood oil), soybean oil, nut oil, sunflower-seed oil, poppy-seed oil, and fish oil. The metallic salts may be manganese, red lead, or litharge. To this preparation is added a volatile liquid such as turpentine or mineral spirits to make the mixture thin enough for brushing.

Varnish made of amber gum is considered the best, as it dries very hard and its moisture-resistance is very high. Its dark color is sometimes a drawback, however. Zanzibar and kauri gums are considered to be the next best for preparing varnish.

The preparation of the varnish has an important bearing on its use and durability. The proportion of oil and gum has a great deal to do in determining its use. Oil varnishes can be grouped into three classes: long-oil, medium-oil, and short-oil. The long-oil varnishes are designed for exterior use where durability is of utmost importance. In this group are such varnishes as spar varnish, wagon varnish, automobile and coach varnish, and agricultural implement varnish. The oil-gum proportions used in preparing these varnishes range from 25 to 50 gallons of oil to 100 pounds of gum.

The medium-oil varnishes are designed for use on interiors such as cabinets, woodwork, and floors. They produce a hard glossy surface that is extremely durable. They are prepared by mixing from 12 to 30 gallons of oil to 100 pounds of gum.

The short-oil varnishes are designed for use on furniture. They dry quickly, producing a hard surface with a high gloss. They are not so durable as the medium-oil or long-oil varnishes, but they are highly satisfactory for the right purposes. They are prepared by mixing from 4 to 6 gallons of oil to 100 pounds of gums.

Spirit varnish. Spirit varnishes, the most common of which is shellac, are prepared by mixing a gum resin called *lac* with alcohol. The natural lac when mixed with alcohol is bright orange, and is called orange shellac. White shellac is produced by bleaching the natural gum and then mixing it with alcohol. Denatured alcohol is most commonly used in the preparation or thinning of shellac. Pure grain alcohol is considered better for shellac, but it is expensive and difficult to obtain.

The shellac most commonly sold in liquid form is a *4-pound cut.* This means that 4 pounds of dry shellac gum was dissolved in 1 gallon of alcohol. For general use a 3 or 3½ pound cut will be found satisfactory. A 4-pound cut can be thinned by additional alcohol.

Shellac is used extensively as a liquid filler for furniture and interior woodwork. It is brushed on the surface in thin coats, then sandpapered lightly after it has hardened to remove the shellac from the surface. The shellac that wedges into the pores of the wood remains there, tending to seal the pores.

Shellac is one of the best materials for finishing furniture. The dull luster on expensive pieces of furniture is frequently produced with it. Shellac is one of the most expensive finishes to apply, requiring from 8 to 10 coats before the work is completed.

Shellac is readily affected by moisture and dampness, and should never be applied when these conditions are present, nor should it be used on furniture that may be exposed to these conditions after the finish has been applied.

Japan varnishes. The most common japan varnishes are known as japan driers. They are most often used to mix with paints to speed the drying time. They are made in solutions containing metallic salts such as manganese, red lead, or litharge; gums or resins; oils; and volatile liquids such as turpentine and mineral spirits. It should be noted that the materials used in the preparation of a japan are identical with those used in an oil varnish, but because of a difference in proportions a solution having a different consistency is produced. Japan varnish is also used by manufacturers in the grinding of paints, enamels, and pigments.

Black japan varnishes usually contain asphaltum, which is a natural product found in many places throughout the world. These black japan varnishes are prepared for air drying, semi-baking, and for baking at high temperatures. The most common use to which these japan varnishes are put is for finishing machines and machine parts.

6. SAFETY

Most finishing materials are highly combustible, and should therefore be handled and stored with care. When preparing or using paints or solvents, all open flames should be avoided. If it should be necessary to have an open flame in the same room after using any combustible, the room should be aired out thoroughly before the flame is made. Any solvent that is spilled should be wiped up immediately, for most of them volatilize readily, filling the room with an explosive mixture.

All finishing materials should be kept in closed metal containers and stored in a fireproof cabinet. The storage cabinet should be located in a cool place, away from heat and open flames.

Rags that are used for wiping should be handled with care. They should never be carried around in a pocket or rolled up in a ball and discarded. An oil-soaked rag confined in a warm place for some time will burst into flame due to spontaneous combustion. Such rags should be put in closed metal containers that are emptied daily.

H. WOODWORKING SKILLS AND KNOWLEDGE

Through your study of woodworking you have been acquiring new skills and learning some new things. The table on page 227 lists the most important of these and suggests a number of jobs, projects, and exercises in which you can put your new skills and knowledge to work for you. The numbers following each item show the pages on which that item is discussed, if you should want to look up any of them.

THINGS YOU SHOULD BE ABLE TO DO	THINGS YOU SHOULD KNOW	SUGGESTED JOBS, PROJECTS, AND EXERCISES
Make out a list of materials and stock sizes, 146–150.	How to read a drawing to determine exact sizes and number of pieces needed, 150–151.	Make the following: A first-aid splint. A first-aid stretcher.
Measure stock to lengths and widths, 152–155.	How to lay out work with the least amount of waste by using a rule, square marking gage, and or a pattern, 4–15, 152–159.	Replace wood seats in trucks. Make the following: A sawhorse. A bench seat. A table (outdoor). Some camp stools. A tool box. Some tool handles. Some tent pegs. A target frame. A rope winder. Some tool racks. Some gun racks. A bulletin board. Some display boards. Bases for electrical appliances. Some poles. Some shelves. Some bins. Some boxes. Some stair treads. Some small ladders. A workbench.
Crosscut and ripsaw to a line, 160–163.	The condition of material (wet or dry), 142–146. The amount of saw set, the shape and size of teeth, 31–32. How to file a saw, 38.	
Cut curves, 35–36 and 158–159.	The uses of the coping saw, 35–36, and 162–163; turning saw, 164; compass saw, 35, 164; spokeshave, 63, 64, 164, and 170; and rasp, 71 and 170. How to smooth curves with sandpaper, 213.	
Square stock to the finished size, 165–168.	How to plane surfaces, the end grain, and the edge of lumber, 165–166.	
Use boring tools, 15–25 and 168–169.	How to bore "through" holes with auger bits, 168. How to counterbore, 200. How to adjust and use expansive bits, 20. How to use a twist bit, twist drill, and countersink, 17–18, 21, 169–170, and 199–200.	

THINGS YOU SHOULD BE ABLE TO DO	THINGS YOU SHOULD KNOW	SUGGESTED JOBS, PROJECTS, AND EXERCISES
Determine the type of wood joint best suited to a particular construction problem, 171–191.	Types of wood joints, 171–191. Strength of various joints, 171–191. Methods of securing joints (with glue, dowels, nails, screws, etc.), 192 211.	
Construct wood joints, butt, half-lap, rabbet, etc., 171–191.	How to lay out joints with a knife and a trysquare, 7–8, and 183–184. How to use special tools in joinery (hacksaw, chisel, router, plane, combination plane, etc.), 36, 43–46, 52–64, 176, 178, 181, and 189–191.	
Nail together wood assemblies, 192–196.	Kinds of nails and their special uses, 192–196. Stagger nail procedures, 195. Toenailing, 196. Causes of injury to wood, 195–196. Loose hammerhead, nicked or wet ball face, 27.	
Fasten pieces of wood together with wood screws, 197–202.	The sizes, types, and uses of screws, 197–202. How to select drill sizes for pilot and clearance holes, 199–200, and Table 11, App. A. How to determine depth of countersink for flathead and oval-head screws, 169–170. How to use a ratchet brace and a screwdriver bit, 201–202.	Reinforce legs and other parts of furniture.

THINGS YOU SHOULD BE ABLE TO DO	THINGS YOU SHOULD KNOW	SUGGESTED JOBS, PROJECTS, AND EXERCISES
Locate positions and insert dowel pins, 209–211.	How to align and match centers for dowels, 210–211.	Glue up narrow boards for table tops.
Prepare wood for finishing, 211–213.	How to determine the proper protective coating, 222–226.	Prepare old painted surfaces.
Paint wood surfaces for interior use, 222.	The composition of paints, 218–222. How to mix and match colors, 220–222. How to apply paint, 222–223.	Repaint and restore painted surfaces.
Paint exterior wood surfaces, 223.	Purpose of sealing coats, 219, 223. How to mix outside paints, 200–222. The use of drab paints to minimize reflection (camouflage), 215.	Repaint outside surfaces for protection and appearance.
Preserve paint brushes, 216–218.	Care in handling brushes, 218. Cleaning brushes with proper solvents, 216–218. Storing brushes, 218.	Reclaim and restore old, hardened, and discarded paint brushes.

SUMMARY

1. One of the most important materials in daily use everywhere is wood. In many cases plastics can be substituted for wood, but wood will probably always remain a vital product.

2. Timber is needed for other purposes besides lumber. Standing trees protect the ground from the elements, from floods and soil erosion. They absorb the surplus water from spring thaws and rains.

3. You can tell the age of a tree by its annual rings of small cells and fibers. Both of the two general types of trees, hardwood

and softwood, provide lumber suited for many uses. Different kinds are suited for different purposes.

4. After logging, wood is milled. The manner in which a log is cut into boards and planks is important to the quality of the lumber. It may be plain-sawed or quartersawed. Lumber has been classified into a number of standard grades (9 for softwoods, 7 for hardwoods).

5. In selecting lumber the kind of wood and the sawing, the durability for the purpose planned and, in some cases, the attractiveness of the grain, are to be considered.

6. Lumber is shaped by planing and sometimes by drilling to make it ready for jointing. It may be jointed in a number of ways and the pieces held together by glue or common fasteners, such as nails and bolts. Sometimes the fasteners are concealed.

7. Paints, varnishes, and other coverings are used to protect wood from the effects of moisture and to provide a surface which resists discoloration and spotting. The painter should have a knowledge of the proper solvents for paint mixtures, of different kinds of brushes, and of safety measures to prevent fires from combustibles.

How many of the following terms can you define or explain?

Annual rings
Medullary rays
Edge grain
Heartwood
Sapwood
Conifer
Deciduous
Dado joint
Countersinking
Warping
Kerf
Sawhorse
Jointing
T-bevel
Framing square

SELF-TESTING EXERCISES

ANSWER THESE QUESTIONS

On a separate sheet of paper numbered from 1 to 5 write the letters for the phrases that answer the following questions correctly.

1. In what way is a hand ripsaw used to cut wood? (*a*) Across the grain; (*b*) diagonally through the grain; (*c*) to make a zigzag edge; (*d*) with the grain.

2. In sawing wood the blade must always be kept at a certain angle. Which of the following is correct? (*a*) 60°; (*b*) 90°; (*c*) 81°; (*d*) 45°.

3. Which of these instruments may be used in the finishing or smoothing of curved surfaces? (*a*) Paring chisel; (*b*) framing square; (*c*) block plane; (*d*) T-bevel.

4. What kind of joint is formed by crossing two pieces of wood so that the surfaces are flush? (They may be crossed at any point and angle.) (*a*) Rabbet joint; (*b*) mitre joint; (*c*) cross-lap joint; (*d*) butt joint.

5. What is the name for the part of a nail to which the head is attached? (*a*) Brad; (*b*) shank; (*c*) escutcheon; (*d*) dado.

Complete These Statements

On a separate sheet of paper numbered from 1 to 16 write the words needed to fill correctly the blank spaces in the following sentences.

When a hardwood log is sawed so as to expose the medullary rays it is (1) wood. The method of sawing which has the least amount of waste is (2) sawing. The process by which wood is dried for commercial purposes is called (3) . Trees will season more slowly if cut in the (4) than if cut in the (5) . In ordering lumber you have to know the length, width, and thickness. The thickness is the measurement from (6) to (7) . The three main processes necessary in making lumber out of rough-cut wood are (8) ., . (9) , and (10) . When preparing to saw wood a carpenter can lay out the angles by the help of either (11) or (12) . The work of fitting together two or more pieces of stock that have been prepared by any of the woodworking operations is known as (13) . When you are driving a nail into the end of the wood (parallel to the grain), the shank of the nail should be (14) than when you are driving it across the grain. A clearance hole is bored through two or more joints of wood so that (15) can be driven through to hold them together. Brushes used for shellac and spirit-stain should be cleaned in (16) ..

QUESTIONS

1. Do you get more lumber from a plain-sawed log than from a quarter-sawed log? What is the disadvantage of boards made from plain-sawed logs?

2. What method must be used to season a piece of wood that will be used for cabinet work or patternmaking?

3. Why does it take longer to season wood for airplane construction than wood for general cabinet work, although the first should have a higher moisture content?

4. What is one important advantage of storing wood out-of-doors in the winter, aside from the speed or slowness of drying?

5. If you have difficulty in using a saw, what may be the reasons? Give three.

6. If you want to drive nails close together and yet follow the grain of the wood, how can you do it so as to avoid splitting?

7. Should wood for outside or inside use have a greater moisture content? Is it satisfactory to glue together end-to-end or end-to-edge pieces of wood?

8. Which cutting tool would you use to cut sandpaper?

V

Metalworking

INTRODUCTION

Look about your home, your school, a farm, the wharves, a factory building — and see how much metal is used. Then imagine the results if suddenly we were prevented from using metals of any type in our various daily activities. What would happen to our factories, our transportation and communication systems, our homes, our buildings, amusement, and education? How important are metals in our daily lives and in our civilization!

1. ELEMENTS AND ALLOYS

There are many kinds of pure metals, called *metallic elements* by the chemist. Some examples are iron, aluminum, nickel, copper, lead, tin, zinc, and magnesium. *Alloys* are mixtures or combinations of two or more metals; examples are bronze, brass, stainless steel, and babbitt metal. Bronze is an alloy of copper and tin, and is used for hardware, coinage, bells, musical instruments, and the like. Brass is an alloy of copper and zinc, and has much the same use as bronze. Stainless steel is an alloy of iron, carbon, chromium, nickel, and copper. Babbitt is mainly tin with some copper and antimony; its chief use is in lining the bearings of engines and machines which are subject to much friction. There is no limit to the possible number of alloys, for alloys differ both in the pure metals they contain and in the proportion in which they are mixed.

Metallic elements and their alloys can be treated in a great variety of ways. They can be *molded*, that is, melted and poured into forms. They can be stamped or pressed into shape.

They can be worked on lathes and milling machines which cut away metal to shape it. They can be heated and beaten as the blacksmith forms a horseshoe.

2. STOCK FORMS

Sheet metal. Metal is supplied to industry in a variety of forms, such as sheet, plate, bar, wire, and band. The form most often used by industry is *sheet metal,* such as sheet copper, brass, steel, and aluminum. To keep sheet steel from rusting, oxygen in the air must be kept from it. This is best accomplished by *galvanizing,* or dipping the steel sheets into melted zinc, which places a rustless layer of the zinc on the steel. A cheaper but less satisfactory method is coating the steel sheet with black pigment. Sheet metals vary in thickness, size, hardness, and springiness.

Plate metal. Plate metal comes as tin plate and steel plate. Tin plate is steel covered with a protective coat of tin, which not only prevents the steel from rusting but prevents most food acids (such as vinegar) from attacking it. Therefore it is excellent for manufacturing cans for food preservation.

Bands. Bands are narrow, heavy strips of steel plate, sometimes called band iron or strap iron. Angle iron is also made from the same material.

Bars. Bars may be round, half-round, square, flat, or many other shapes in cross section. Cold-rolled steel bars have harder texture and greater stiffness than bars of hot-rolled steel. Copper and brass bars may be solid, or hollow in the form of tubing.

Wire. Wire is generally made by pulling, or *drawing,* various metals in the form of round bars through small holes in thick, hard pieces of metal called draw plates. First the bar is drawn through a hole a little smaller than the diameter of the bar. The process is repeated, the size of the holes used being gradually reduced until the desired diameter is obtained.

Various metal forms are generally used according to certain ranges of width, length, and thickness. These are given in Table 19, Appendix A.

3. IRON AND STEEL

Cast iron. Cast iron belongs to the group of metals called the *ferrous* metals — metals that are made largely of iron. The cut surface of a piece of gray cast iron will blacken a finger much as a "lead" pencil does. In both cases the blackening of the finger would be produced by the same substance, *graphite.* It is the presence of graphite that distinguishes cast iron from the other ferrous metals and that gives cast iron its characteristic properties.

When a casting is made, the molten iron is poured into a mold which has been made of specially prepared sand. As the metal cools off and becomes solid, graphite separates out in fine particles.

Think of a fine-grained sponge with pure iron substituted for rubber in making it. Throughout this sponge a great number of thin sheets of very hard material crisscross through each other. All the space not occupied by the pure iron and the thin sheets of hard material is filled with finely powdered graphite. Roughly, this imaginary sponge will illustrate the structure of a gray-iron casting. The thin sheets of hard material are called carbide of iron because they are formed of iron combined with carbon.

When molten iron is first poured into a mold, the carbon is combined with the iron. As the metal cools and becomes solid, the carbon separates from the iron. This carbon is the graphite we find in the casting. The graphite needs space, so as it deposits out of the solution, the casting swells. The swelling of the casting causes all the small spaces to be filled and produces what foundrymen call "sharp" castings.

There are, then, three principal parts to a gray-iron casting: (1) a honeycomb structure of pure iron called *ferrite;* (2) reinforcing sheets of carbide of iron called *cementite*, which crisscross through this honeycomb; and (3) graphitic carbon which fills the space in the structure.

The ferrite binds the whole structure together. The cementite furnishes the rigidity so valuable in machine structures where the slightest deflection is reflected in inaccuracy. The graphite produces the swelling that makes for sharp castings and makes castings easier to machine.

In lathes, shapers, and milling machines, the castings which hold the moving parts are made of cast iron, and it is the presence of the thin sheets of carbide of iron that makes these castings so rigid. Automobile engines are made mostly of it. Tools such as lathes, planers, and milling machines are more than ninety per cent cast iron by weight. The making of gray-iron castings is one of the great branches of industry.

There is, of course, very much more to know about it. Substances such as silicon, manganese, vanadium, and sulfur impart characteristics which vary with the degree to which these substances are present. The size of a casting, its shape, the rate at which it is cooled, and many other factors are studied by specialists who devote their entire time to the making of gray-iron castings.

Malleable iron. Malleable iron meets the needs for a material which has properties about halfway between those of steel and of cast iron. Its chief virtue is its ability to resist repeated shock. Its manufacture consists of two distinct steps. First, the casting is made of white iron. White iron is the same substance which appears in gray iron as carbide of iron or cementite. In white iron, care is taken to have just the right amount of carbon present; and by control of the melt, this carbon remains combined with the iron so that the entire casting contains only cementite when it cools.

After cleaning comes the second step. The castings are packed in a suitable material such as iron scale, sand, and lime in various proportions and then heated to about 1400° F. This temperature is maintained for about 60 hours. The castings are then allowed to cool very slowly, during a period of from 2 to 5 days. During the heat treatment, the carbon in the castings works out to the surface and is oxidized. Some remains in the form of temper carbon. The slow cooling accomplishes two things: it oxidizes the carbon and it thoroughly *anneals*, or toughens, the casting.

Malleable castings are widely used. In small castings such as those used in locks, scales, and gun parts, the process is especially effective because decarbonization is more complete than in parts which have thick sections. Thin malleable castings can be bent into a U-shape while cold without fracture. Malleable castings should not be welded. They *can* be welded, but the melting which takes place during the welding undoes the effects of the annealing and the resulting joint will be of uncertain quality. However, malleable castings can be successfully *brazed*, or soldered with hard solder or brass.

Annealed gray iron. In recent years a material closely resembling malleable iron, and sometimes confused with it, has been coming into use. It is called *annealed gray iron.* It is extensively used in vise castings and to replace malleable iron in farm machinery. It can be made much more rapidly than malleable iron, and in some ways is superior to it. The process is simple.

Gray-iron castings are placed in an uncovered, wrought-iron box, called an open muffle. A gas flame is used to raise the temperature to about 1550° F A lid is then placed on the box and the flame turned off. In about 15 minutes the castings are cooled to black heat and may be removed. Castings treated in this way stand much bending and possess many of the properties of a mild steel.

Wrought iron. Low-carbon steels have displaced wrought iron for many uses, but it still is used to meet many special requirements. Some designers specify its use in chains. One type of work for which it is specially fitted is ornamental ironwork, such as grills and fireplace equipment. It lends itself to this work because it is easily welded on the anvil or with a torch. It can be shaped and bent into intricate forms. It differs from mild steel chiefly in the fact that it contains evenly diffused slag. The hand process used in making it is *puddling.* In this process, pig iron is melted in a furnace so constructed that the hot gases coming from a fire are deflected down upon the top of the charge of iron, which has been placed on a hearth separated from the fire by a wall of heat-resisting brick. The hearth is coated with iron oxide and the charge covered with the same material. As soon as the metal melts it is stirred by a heavy iron bar called a *puddle.* As carbon and impurities are burned out, the molten mass becomes pasty. When in this condition it is formed into balls, lifted from the furnace, and hammered or rolled into bars.

Chemical processes, such as the Ashton process, are coming into use because they produce the same results as puddling.

Inferior wrought iron is made by binding scrap together, heating it to a welding temperature, and then hammering or rolling it into bars. Wrought iron does not become fluid, so it cannot be used for casting.

Steel. If all the carbon and impurities are removed from cast iron and then an amount of carbon up to 2 per cent added in such a way that it combines with the iron, steel will be produced. If a very small amount of carbon is so combined, the steel will be very soft and so closely resemble wrought iron that only expert inspection could detect the difference. This steel of low-carbon content is the steel used in building bridges and making the frames of skyscrapers. It can be forged, rolled, or welded. If more carbon is added, the steel takes on a new property; it can then be made very hard by heating it to red heat and cooling it quickly. It is then called *tool steel.* This is the steel used for making files, chisels, and cutting tools. It has a remarkable property in that after it has been hardened it can be tempered to intermediate degrees of hardness. This property of carbon steel is employed to increase the usefulness of the hammer head. It is first hardened and then, by a reheating process which the blacksmith calls *drawing,* it is slightly softened. Somewhat different treatment is given to that part of the hammer head through which the handle passes, called the *eye.* It is drawn by the blacksmith until it is much softer than the face and peen. The result of this treatment is that the face and peen are hard enough to resist the effect of blows and the eye is left tough enough to keep from splitting open from the effects of repeated shock.

A very hard cold chisel could not be used; it has to be tempered. A simple way to temper the chisel is to brighten its surface with a piece of emery cloth and then heat it. As it becomes hotter, the color of the brightened surface changes. This change in color is produced by oxidation, and indicates the temperature. If the chisel is to be used for ordinary work, it is plunged or cooled just as the cutting edge starts to turn blue, for it can then be tempered. Some tools would be cooled at dark-straw color and some at a light-straw or yellow, depending upon the use to which they are to be put.

Tool steel, because of its properties, has become one of the most useful materials employed in industry. It can be annealed so that it is easy to work with files or other metal-cutting tools. Annealing consists of heating a metal red-hot and then letting it cool very slowly. After the annealed piece has been shaped as desired, it is hardened and tempered. Dies, punches, and a great variety of tools used in manufacture are made in this way.

Alloy steels. For many years steels containing combined carbon in varying amounts served the needs of industry. As these needs increased, experiments were made to increase the uses of steel. Great achievements have been made as a result of these experiments. Tungsten, vanadium, nickel, chromium, and other metals have been alloyed with steel, both separately and in combination. The high-speed steels used in making lathe tools, drills, reamers, and other tools are examples of these steels. Chromium has been used to make steel resist corrosion. New alloys are being developed constantly to meet special needs.

4. NONFERROUS METALS

Copper, zinc, lead, tin, aluminum, and brass are the nonferrous metals most commonly used.

Copper. Copper can be worked hot or cold. It can be drawn through dies to produce wires so fine that the eye can hardly see them. It is easy to solder. Copper presents some difficulty in welding because when hot it absorbs gases. When it is hammered or rolled it becomes quite hard. When this occurs, it may be heated and then plunged into water to soften it.

Zinc. As a metal, zinc's most common use is as an alloy of copper and aluminum. We seldom make things of solid zinc, but it can be cast and soldered. It is used in its sheet form for lining tanks and for roofing.

Lead. The most familiar uses of lead are for water pipes and storage batteries. It is easy to cut and shape. It is generally joined by a process which has come to be called *lead burning*, but is really welding. Lead is also added to brass as an alloy to make the brass machine easily, and it is alloyed with tin to make soft solder.

Tin. Tin is used extensively to coat steel; tin cans, for example, are really tin-coated steel cans. We have just mentioned the use of tin in combination with lead to make solder. It alloys with copper to form bronze.

Aluminum. We seldom use aluminum in its pure form. The metal which we commonly call aluminum is really an alloy of aluminum and copper or zinc. When alloyed with manganese or magnesium, aluminum has special properties. It can then be forged, and by special heat treatment can be given great tensile strength; it is then used in airplane construction. Aluminum-alloy castings are made in sand and in metal molds. They can be machined very rapidly. Sheet aluminum can be stamped and drawn into intricate shapes.

Aluminum and magnesium metals will be playing an increasingly important part in the industrial and economic life of America. It has been estimated that America's capacity to produce aluminum will be six times as great at the close of World War II as it was before and that her capacity to produce magnesium will be 89 times as great.

Brass. Brass is an alloy of copper and zinc, with lead added to make it machine easily. Brass is easy to solder; in sheets it can be formed and stamped; and when hammered or rolled, it becomes hard. Brass wire is rolled to make it suitable for use in making springs. If you should wish to soften brass that has been hardened by hammering, you could heat it and then plunge it into water.

A. LAYOUT

When a tailor gets an order to make a suit, he does not cut his cloth by guesswork. He carefully marks the cloth and fits together the patterns for the various pieces so that there will be as little waste as possible. In the same way but with different tools, the mechanic working in the metalshop marks up his material so that he may know exactly where to cut, drill, bend, and so on. The tools most often used for this layout work are the steel scale, the dividers, and the scribers. Others are the square and center punch.

1. APPLICATION OF THE STEEL SCALE

If we were asked to make a pin 4″ long from a steel rod, we should lay the scale against the piece of rod and mark off 4 inches. In doing this, we should have done layout in its simplest form, using one dimension alone. The only tools needed would be the steel scale and something to make a mark with. The steel scale, or rule, used as a layout tool, has already been discussed under hand tools on pages 5–6.

2. THE DIVIDERS

If you were asked to divide the steel rod into parts, to lay off a given distance from some point marked on it, or to repeat a given dimension upon it a number of times, you would use some form of dividers. The dividers, as we have seen, consists of two legs fastened together at one end and pointed at the other. Various forms of dividers, adapted to different purposes, have been discussed on pages 12–15. Similar to dividers are the trammel, used to scribe circles too large to be scribed with a divider, and the compass, which is similar to the divider except that one leg holds a pencil. The trammel and the compass have been discussed on pages 13–15.

3. SCRIBERS

As we have seen, pages 9–14, the dividers, the trammel, and the marking gage are all used to scratch or scribe lines on metal or wooden surfaces. A special instrument called a *scriber* may be used to mark lines on wood or metal when the location of the line has been determined by layout tools. The scriber is a long narrow pencil-like tool. It consists of a long, hard, pointed end on a handle, which is usually knurled to provide a good grip for the hand. Scribers come in many sizes and in different shapes. Sometimes the scriber has a point on each end, one of them bent at a right angle to the rest of the tool. Such scribers have the knurled handle grip in the middle. You may turn them around and use whichever end is more convenient.

4. USE OF THE SQUARE

Suppose we want to lay out a rectangular piece of sheet metal 2″ long and 1″ wide. Now width, as well as length, must be considered. Since the piece is rectangular, its width must be at right angles with its length. If one edge is straight, one arm of the square is lined up with it. Any line, therefore, scribed on the other leg of the square must be at right angles with this first straight edge. Thus, using the proper dimensions, a perfectly rectangular piece can be simply and quickly laid off with the square.

However, if no edge of the metal stock is straight, a steel scale or one leg of the square must be used for scribing a straight line near one of the edges. This straight line is then used as the straight edge for setting the square properly and scribing lines at right angles to it. This principle is basic in all layout work. Start with a line and lay off all other lines in fixed relation to this line.

5. USE OF THE CENTER PUNCH

If holes are to be drilled, a square is used to scribe lines corresponding to the center lines in the drawing. Where these lines intersect, a mark is made by placing the center-punch point on it and tapping the punch once with a hammer. This punch mark will be used later for guiding the drill point in making the hole.

Much of layout consists in locating points. As in the case of the drilled hole, these points are located by intersecting lines. Where they intersect, the center punch may be used to make a light mark. This mark is an aid to the eye when working to the line. It may serve to center the dividers in the process of laying out; should the lines locating the point become obscured or blurred it serves in replacing them.

In sheet-metal work mechanics sometimes lay out the project on a piece of heavy paper instead of directly marking off the metal. In practice this paper, called a *pattern* or *stretch-out*, is laid on the metal and all intersections are transferred by center punching through the paper The layout is then completed by connecting the punch marks with scribed lines.

6. HELPS IN LAYING OUT

In order to make lines and points easily visible, a surface may be rubbed with chalk. Then scribed lines appear dark on a white background.

Machinists and toolmakers often copperplate steel and iron surfaces in preparation for scribing. This is done by thoroughly cleaning the surface and polishing it with emery cloth. A solution of copper sulfate and water is made and kept in a glass or porcelain container. The surface of the steel or iron plate is covered with a thin layer of this solution. Chemical action soon causes a thin layer of copper to be deposited on the steel or iron plate. Washing with clear water removes the chemical and prevents further action. Then fine, accurate markings can be made on the surface.

B. FILING

A *file* is a hard-steel instrument, made in various shapes and sizes, with surfaces roughened to various degrees; it is used for smoothing and shaping materials, such as wood, metal, and plastics. (See Fig. 5–1.) Files were discussed briefly on pages 69–70.

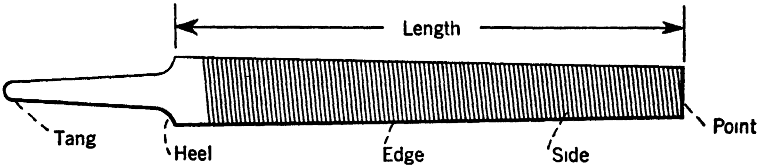


FIG. 5 1. A single-cut flat file.

Three factors control the classification of files: (1) the *cut*, or type of roughness and degree of coarseness of the cutting surface; (2) the *shape*, or cross section; and (3) the *length*, or distance from the point to the heel or tang.

1. KINDS OF FILES

Files in common use are made by chiseling grooves at an angle on the surface of a piece of steel (called a *blank*) which is later hardened. These grooves are called *teeth;* and though generally they run diagonally, they may run crosswise. Not only the surfaces, but the sides or edges of files are toothed. Some files, though, have plain edges and are called *plain-edged files.* They are excellent for use where the filing must be done in corners or cramped places and care must be taken not to mar or scratch adjacent surfaces.

A *single-cut* file has teeth slanting only in one direction, from left to right toward the *point*, or end of the file. (See Fig. 5–2*A*.) This type of file is used with light pressure, and produces a fine, smooth finish on metal surfaces or a sharp edge on such cutting tools as scissors, knives, and saw teeth.

A *double-cut* file has one set of teeth slanting as in a single-cut file with another set, finer than the first, crisscrossing over it in the opposite direction — from right to left toward the point. (See Fig. 5–2*B*.) Greater pressure is used with this type than with the single-cut. Metal is removed faster, and, therefore, the finish is not so smooth.

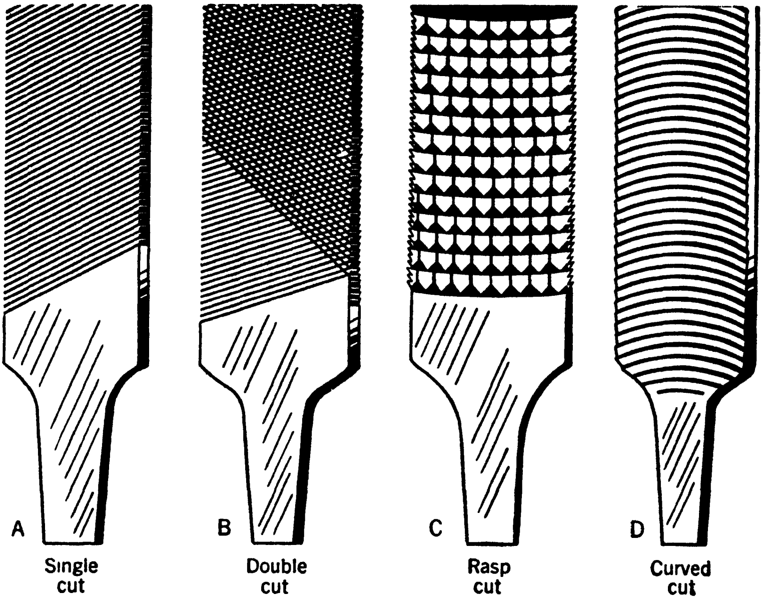


FIG. 5-2. Kinds of file cuts.

A *rasp-cut* file does not have grooves as does a single-cut file. Rather, it consists of rows of individual, separated teeth made by a short, narrow, punch-like cutting chisel. (See Fig. 5-2*C*.) It provides an extremely rough cut and is used chiefly on wood, leather, aluminum, lead, and other such soft materials. It removes material very fast, but leaves an extremely rough finish.

A *curved-cut* file has symmetrical curved grooves extending across its face. (See Fig. 5-2*D*.) It has a rather coarse cut, and is used principally on lead and babbitt.

Coarseness. A file may be single-cut, double-cut, rasp-cut, or curved-toothed; and the distance between the cuts or teeth may also vary. Thus the coarseness of the teeth — that is, the number of teeth per inch — is designated as *rough* (least number of teeth per inch), *coarse*, *bastard*, *second-cut*, *smooth*, and *dead-smooth.*

Note that double-cut refers to the *kind* of teeth and second-cut refers to the *size* of the teeth.

Coarse and bastard cuts are used for heavier work, to remove material speedily where it does not matter if the finished job is coarse or rough. Second-cut and smooth are used for finer work and for finishing off the rough results given by the coarse and bastard files. Rough and dead-smooth are seldom used, except for special work.

Coarseness varies according to the length of the file, the distance from the tip to the tang. In comparing the coarseness of two files, therefore, they must be of the same length. A 6″ file cannot be compared with a 12″ file, since they are of different lengths.

2. SHAPES OF FILES

Another factor that helps in describing the type of file is the *cross section*, or shape of the file if cut across just as bread is sliced. The most common shapes are flat, square, triangular, round, and half-round. There are many other kinds. (See Fig. 5–3.)

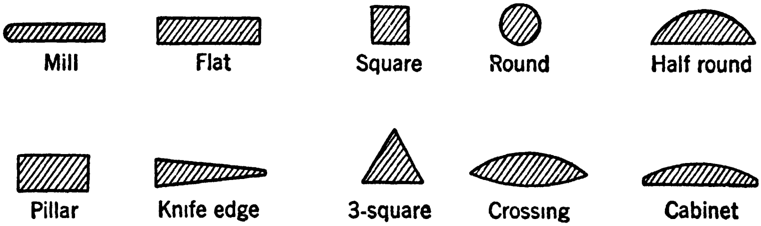


FIG. 5–3. File shapes.

The *flat file*, which comes in a variety of cuts and coarsenesses, is the one most commonly used. Generally it tapers and is a double-cut bastard type, although it is also made second-cut, smooth, or even dead-smooth.

The *mill file* is single-cut and square-edged. Some have one or two round edges. Since fine work can be done with this file and the resulting finish is smooth, the mill file is used for sharpening mill or circular saws, cross-cut saws, and mowing-machine knives, and for lathe work, draw filing, and smooth-finish filing in general.

Machinists' files are used throughout industry when the chief purpose is to remove metal quickly and the resulting rough finish is not of special concern. These files include flat, round, half-round, square, triangular, and knife shapes. Except for small sizes of round and half-round shapes, they are all double-cut.

The *equaling file* is not often used, except for fine-tool manufacture. It ranges from 6″ to 12″ in length and is generally a double-cut bastard type.

The *round file* is used for enlarging round holes and shaping curves. It tapers, and varies in length from 4″ to 18″. The cut is generally single bastard. The round file is sometimes called a rattail or a mousetail.

The *slotting file* (sometimes called *slitting*) is used for filing grooves for cotters (tapered flat rods or pins), wedges, or keys. It is double-cut, usually bastard, and its sides are at right angles to each other.

3. SIZES OF FILES

Figure 5–1 shows the names for the various parts of a file. Length is measured from the point to the heel. Files vary in length between 3″ and 20″.

4. CARE OF FILES

Mechanics should take good care of their files for three simple reasons: avoiding personal injury, lessening labor by using sharp instead of dull instruments, and reducing expense of tools and materials.

Cleaning. Files should be kept clean and free from chips of the material they are used to file. After each few strokes tap the handle (no other part) gently and firmly on the bench to loosen the chips. Files should be frequently cleaned with a file card. (See pages 70–71.) By brushing in the direction the teeth run, the file card removes material that may be clogging the teeth. Usually resting in the handle of the file is a *pick*, which is nothing but a piece of soft-iron wire of heavy gage. It is used for removing stubborn burs or pins jammed between the teeth which cannot be removed by the card alone. A stiff-bristled brush is used for finishing the cleaning job. First the file is brushed in a direction parallel with the teeth, and then along the length of the file. The card, brush, and pick may come as separate pieces or as a combination in one tool.

Pinning is the result of scratching a surface while filing because the file teeth were clogged with the material filed. Carding a file prevents this. *Chalking* a file before it is used on soft metals helps prevent it from getting clogged.

New files are usually coated with oil to prevent rusting. On most jobs this does not give the mechanic any trouble, but in certain instances the oil must be removed before filing. A simple way is to cover the file with chalk and then card off the oil-soaked chalk. An oiled file fails to cut, or *bite*, properly on hard-surfaced material such as cast iron. Such a file may glaze the surface of the material, thus blunting the file teeth. Then, too, dust and filings may pack down in the oil of the file and eventually become so caked and hardened as to render the file useless.

Sometimes a file is so hard-caked that the card cannot help. In such cases it may help to hold the file for a few moments in boiling water. This may soften the caking for easier removal with the card. The heat obtained by the file from the boiling water helps to evaporate any film of water remaining and so prevent rusting.

Rust. Rusting in storage may be prevented by covering the file with a thin coat of oil. However, as we have noted, the oil should be removed before the file is used. If stored for some time, the file should not only be covered with a thin coat of oil, but should also be wrapped in an oiled paper.

General care. It is most surprising to compare the hard work done by a file with the delicate teeth it has. If possible, examine these teeth with a hand magnifying glass and see for yourself. Throwing a file into a tool drawer on top of other tools or throwing other tools on top of a file can only cause damage to the teeth of the file. Handles should be properly placed on all files. Files should be hung up by their tangs on a rack where they cannot rub against each other or be damaged by other tools. The best file handle is the old-fashioned wooden type. It should be of proper size and should reach almost to the shoulder of the file.

The teeth of a file slope at such an angle as to provide for pressure and the resultant cutting while the file is being pushed. If the pressure is maintained on the return stroke, the teeth are broken off.

Filing of sharp edges and hard surfaces should be begun with an old file and then continued and finished with a new file. If the new file is used in such cases from the beginning, its teeth may be damaged.

5. USE OF FILES

To one who has not done it, filing looks very simple. However, to hand file a perfectly straight flat surface is one of the most difficult operations in the metalshop. On the other hand, with sufficient practice and by conscientiously following several simple rules, the skill can be mastered.

Selecting the file. In general, the selection of a file depends on the type of metal, the shape of the piece, the shape it is to be filed, and the degree of accuracy required.

Begin with a bastard-cut file for filing brass, bronze, or cast iron and finish with a second-cut file, or smooth-cut file for the first two materials.

For filing aluminum, lead, or babbitt, use a bastard file or a float-cut file. (See Fig. 5–4.)

Use a file of proper length for the work: a short file for a short piece; an 8- or 10-inch file for medium-sized work; and a file as large as can be conveniently used for larger work. Large

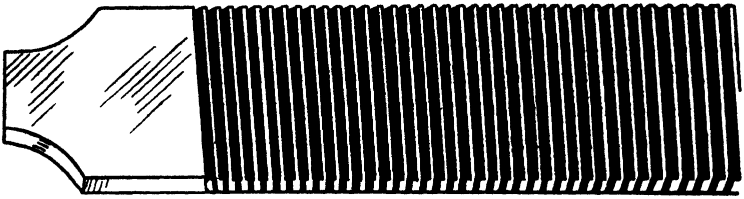


FIG. 5-4. A float-cut file.

areas should be smoothed with large, rough files. Small areas should be filed with small files with bastard or second-cut teeth.

It is logical that when a square edge is required, a round file should not be used. For slots, a slotting file should be used; for enlarging circular holes, a round file should be used; and so on.

For general use, where great accuracy is not required, the bastard file is used. For close fits and preparing surfaces for polishing, the final filing should be done with a second-cut or smooth file.

General filing instructions. (1) Select the proper file for the particular job.

(2) When mounting a handle on a file, never drive the tang into the handle; always drive the handle onto the tang. First drill a pilot hole in the handle. Place the tang into the hold and strike the handle suddenly and sharply on top of the work table. The weight of the file will drive the tang into the handle.

(3) If the handle becomes loose, tighten it as just explained for mounting.

(4) Especially for a beginner, the more slowly the file is pushed the less chance there is of rounding a corner of the work while trying to square it.

(5) Have the work held securely, as in a vise. The part to be filed should just project over the jaws of the vise. If it projects too much, the work will vibrate with each motion of the file and hinder you.

(6) The vise (and therefore the work) should be at a height

level with your elbow. At this height you have a free and easy swing of your arms from the shoulders.

(7) Assume a comfortable position; use long strokes while moving the file.

(8) Avoid as much as possible separate movements of wrist and elbow.

(9) Keep the file in good condition, as previously explained.

Flat filing. *Flat filing* (sometimes called *smooth filing*) is a means of giving a fine, smooth finish to the surface of metals. Figure 5–5 illustrates flat filing. Hold the file handle in the right hand, palm down. Hold the point in the palm of the left hand, palm down, with the fingers curved around it. Do not rely only on the motion of the arms while filing. Move the body forward on the cutting stroke; straighten the body on the return stroke.

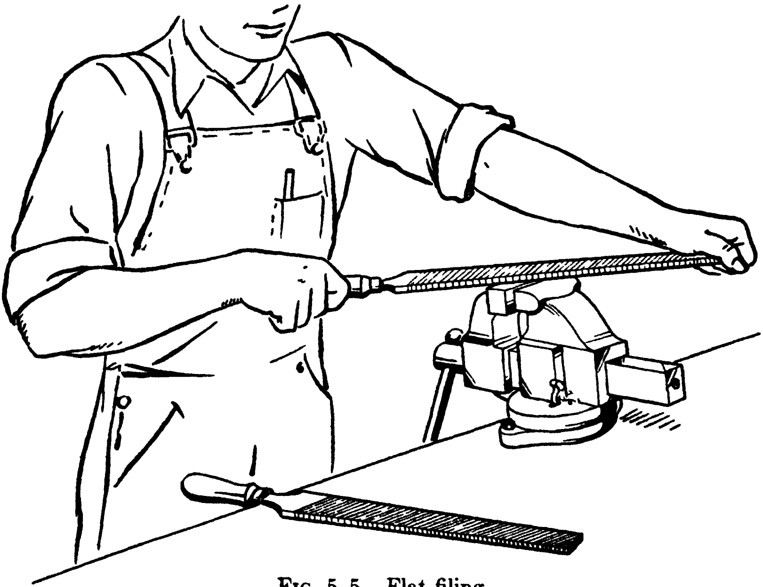


FIG. 5–5. Flat filing.

Hold the file flat; avoid rocking it. At the beginning of the stroke put pressure on the file with the left hand. As the stroke moves forward, reduce this pressure and replace it with pressure from the right hand. Alternate pressure in this manner for each cutting stroke.

Draw filing. *Draw filing* makes a smooth and level surface. It consists of grasping the file firmly at each end, the handle in the right hand, and alternately pushing and pulling the file sidewise across the work. Figure 5–6 illustrates draw filing. Note how the hands are held and the position of the thumbs. Pressure should be even between the two hands and should be applied during the cutting motion. On the return motion, the file should be lifted away from the work. Ordinarily a standard-mill bastard file is used, but a single-cut smooth file will do. If some chalk is rubbed on the file, the finish is improved.

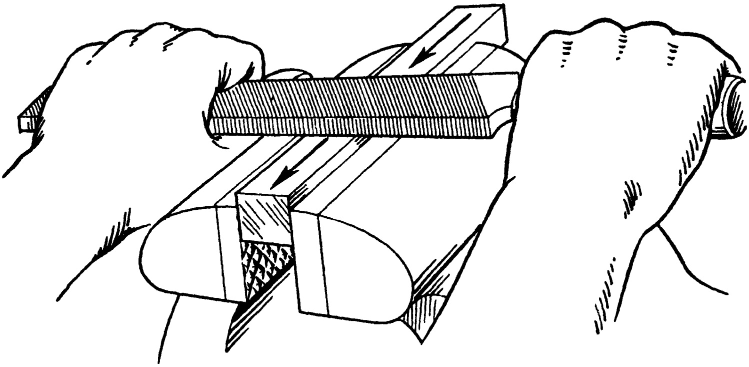


FIG. 5-6. Draw filing.

A still smoother surface can be obtained by wrapping fine emery cloth around the file and then proceeding as if for draw filing.

Shape filing. Round surfaces should be filed with a rocking motion, as shown in Figure 5–7, but following the general directions for flat filing.

Emergency file substitute. In an emergency, when no file is available, metals can be "filed" by rubbing them with a hard, flat, smooth stone. This will not produce the desired effect, but it can help greatly.

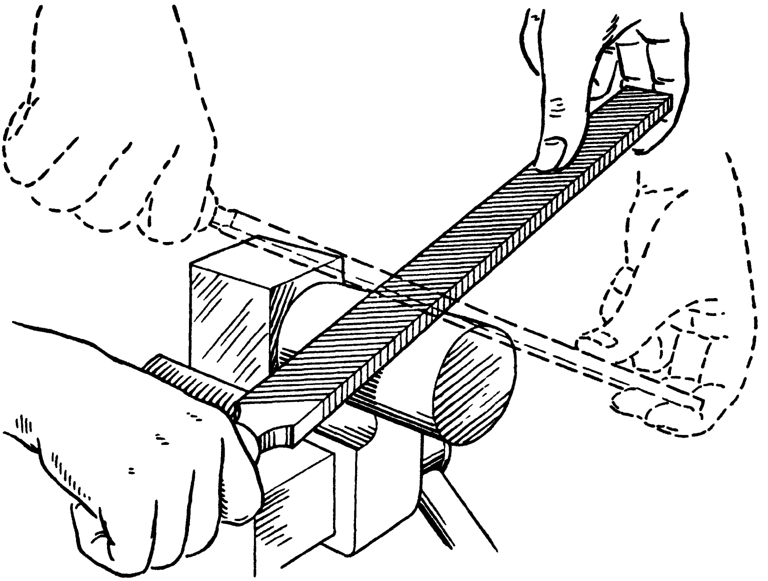


FIG. 5 7. Filing round surfaces.

6. SAFETY PRECAUTIONS

To avoid accidents and to prevent loss of tools and materials, certain safety precautions should be followed: (1) Follow the general directions for the proper care and use of files.

(2) Never use a file without a handle. Without a good handle properly mounted, it is possible under certain conditions for the tang of the file to be pushed into the palm of the hand.

(3) Files are tough tools that can stand a lot of wear with proper handling, but they are necessarily made of material that can crack almost as easily as glass. Therefore, nothing should be done with or to a file that will break it.

(4) Do not use a file as a hammer. It will break and the piece flying off may hurt someone. Likewise, do not use it for prying covers off cans.

(5) Do not use an old rattail file with a sharpened end as a center punch. It will break under the blows of a hammer.

C. HACKSAWING

The metalworker uses a hacksaw for cutting metal just as the carpenter uses the crosscut and ripsaws for cutting lumber. The hacksaw consists of a rigid frame with replaceable saw blades.

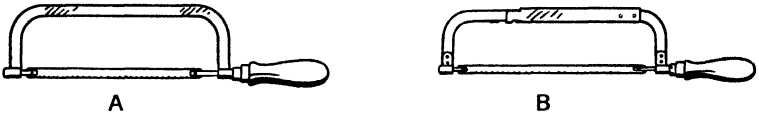


FIG. 5–8. Hacksaw frames with solid back (*A*) and adjustable back (*B*).

The frame, as illustrated in Figure 5–8, may be solid or adjustable. An adjustable frame, since its length can be changed, will take blades of various lengths. A solid frame takes a blade of just one length.

1. SELECTION OF GRADES OF HACKSAW BLADES

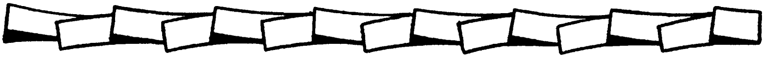
Hacksaw blades are made of tool steel, properly tempered. The all-hard type is hardened throughout; only the teeth are hardened in the flexible type. Blades range in length from 6″ to 18″. Length is the distance between the two holes, one near each end of the blade. The blade is mounted on the frame by inserting the frame pins (on each end) in the blade holes. Blades are from $\frac{7}{16}''$ to $\frac{9}{16}''$ wide and are 0.025″ thick. They contain from 14 to 32 teeth per inch. (The number of teeth per inch is called "pitch of teeth.")

Hacksaw frames are so constructed that the blade can be attached parallel to the frame or at right angles with the frame. Hacksaws were discussed earlier under hand tools, on pages 36–37.

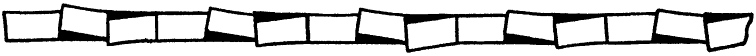
2. DIRECTION OF TEETH WITH RELATION TO CUTTING STROKE

If the teeth of any saw are just as thick as the rest of the saw, there is no clearance for moving the saw through the material; there is no space for the chips to come out. The result is that the saw binds. Therefore there must be a set to the teeth of the hacksaw blade. This set consists of a slight bend to the teeth so that they are at a small angle to the rest of the blade. With the teeth thus set, the saw makes a cut a trifle wider than the rest of the blade. This was explained in detail under hand tools, on pages 31–33.

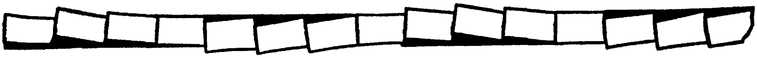
Hacksaws have three kinds of set: alternate, raker, and undulated. (See Fig. 5–9.) With *alternate set*, every other tooth is slightly bent to one side and all the other teeth are slightly bent to the opposite side. In a *raker set*, every third tooth remains straight, or unbent. The other teeth are bent as they are in alternate set. When the set is *undulated*, short sections of teeth are bent in opposite directions, the teeth in each section gradually increasing and decreasing in degree of bend.



Alternate set



Raker set



Undulated set

Fig. 5–9. Set of hacksaw blade teeth.

3. SELECTING BLADES

In choosing the correct blade for the particular job, there are two main considerations: (1) Should it be all-hard or flexible, and (2) what should the number of teeth per inch (pitch) be? The answers vary:

(1) For brass, tool steel, cast iron, rails, and other stock of heavy cross section, use the all-hard blade.

(2) Use a flexible blade for hollow shapes and metals of light cross section, such as channel iron, tin, tubing, copper, babbitt, and aluminum.

(3) Use a coarse pitch, such as 14 teeth per inch, on machine, cold-rolled, or structural steel.

(4) Use an 18-tooth blade on solid stock, aluminum, tool steel, babbitt, high-speed steel, cast iron, and the like. In fact, this pitch is for general use.

(5) For tubing, tin, copper, brass, channel iron, and sheet metal of over 18 gage, use blades with 24 teeth per inch.

(6) For thin-wall tubing, conduits, and sheet metal thinner than 18 gage, use blades with 32 teeth per inch.

4. USING THE HACKSAW

(1) Select the proper blade, as explained in the previous section.

(2) Mount it tightly in the frame.

(3) Mark the stock where it is to be cut, with a scriber, pencil, or soapstone. If high accuracy is required, mark the place with a file cut. This can be used to start the saw.

(4) Grip the work tightly in the vise so that the place of cutting will be very near the jaws of the vise.

(5) To prevent marring the work by the clamping of the vise jaws, wood or a softer metal should be placed between the work and the jaws. To hold oval or circular work in a square-jaw vise, filler pieces of wood, leather, or copper should be used to grip

the work and prevent scarring. Be sure that metal fillers are bent down over the jaws of the vise out of the way of your fingers.

(6) Expose as much surface as possible of any odd-shaped work, so that a corner can be cut gradually, not sharply. In this way, a maximum number of teeth can engage the work at one time.

(7) Start hacksaw cuts by having the blade almost parallel to the surface along which the cutting is to be done — never at a broad angle to it.

(8) The teeth of the blade should always point toward the work and away from the worker. Mounting the blade in the frame in this manner makes the cutting take place on the pushing motion, away from the body.

(9) At the end of the pushing motion, relieve the pressure on the saw, lift it slightly, and then draw the blade straight back. Never saw faster than 60 strokes per minute.

(10) After starting the cut with a number of short strokes, make all other strokes as long as possible without banging the saw frame against the work.

(11) Always keep the blade at the same angle. Changing the angle will bind the blade in the cut and prevent its being moved.

(12) In cutting very thin metal, place the work between two pieces of wood or soft metal or against one piece of thick wood alone. Cutting through this assembly prevents chattering, produces a smoother cut, and avoids damage to the material.

(13) To make a cut deeper than the frame, turn the blade sideways, as shown in Figure 5-10.

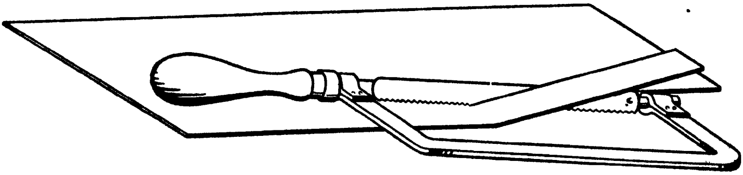


FIG. 5-10. Making a cut deeper than the hacksaw frame.

(14) When the work is nearly cut through, raise the saw slightly to prevent the teeth from catching.

5. SAFETY PRECAUTIONS

(1) Do not bear too hard on the cutting stroke. The strain may break the blade, and when the pressure is suddenly removed the blade or material may jab into your hand.

(2) Keep the blade cutting in the same direction all the time. Twisting the blade may break it and result in an accident.

(3) Do not use a blade with broken teeth, for they prevent smooth sawing strokes. When the jagged part of the broken teeth hits the work, the saw may jump out of the cutting groove and throw you off your balance.

(4) If the work is not held tightly in place, it may slip and break the saw blade.

(5) Slow up the last few cuts. Towards the end, the saw may cut through suddenly and let your hands hit on the sharp edges of the metal.

(6) When using filler pieces of metal in a vise to prevent scarring the work, be sure that they are bent down over the vise jaws. Jagged edges sticking up in the air may cut your fingers.

6. POWER HACKSAWING

Just as the woodworking shop has its circular saw, so the metal shop has its power hacksaw. The power hacksaw does all the work just described for hand hacksaws, but does it more efficiently and more quickly. The power hacksaw is found in every machine shop except the very smallest. It is used for cutting up bar stock, tubing, pipe, and similar metal forms.

D. DRILLING—HAND AND POWER

There are two common ways of making holes in metals, punching and drilling. Punches may be *solid*, similar to a center punch with a flat end; *hollow;* or *hand*, similar to the pliers type used in making holes in paper. Drilling provides greater accuracy and a wider variety of sizes of holes than punching. Punching can be done only on sheet metal of rather thin gage; drilling can be done on all metals regardless of their thickness.

Drilling is the operation of cutting holes into or through metal by means of a rotating tool with cutting edges at its point The machine that rotates the drill is called the *drill.* The cutting part, or *drill point,* being removable, can be replaced if broken; and it can be sharpened when it becomes dull.

Drills. If the machine is operated by hand, with hand pressure, it is called a *hand drill.* (See Fig. 5–11*A*.) The largest size drill it takes is $\frac{3}{8}''$; therefore it is generally used only for light, small work. If operated by hand but with pressure applied by placing it at the chest and using the weight of the body for pressure, it is called a *breast drill.* (See Fig. 5–11*B*.) A breast drill is generally used for heavy-duty work. It may have a two-

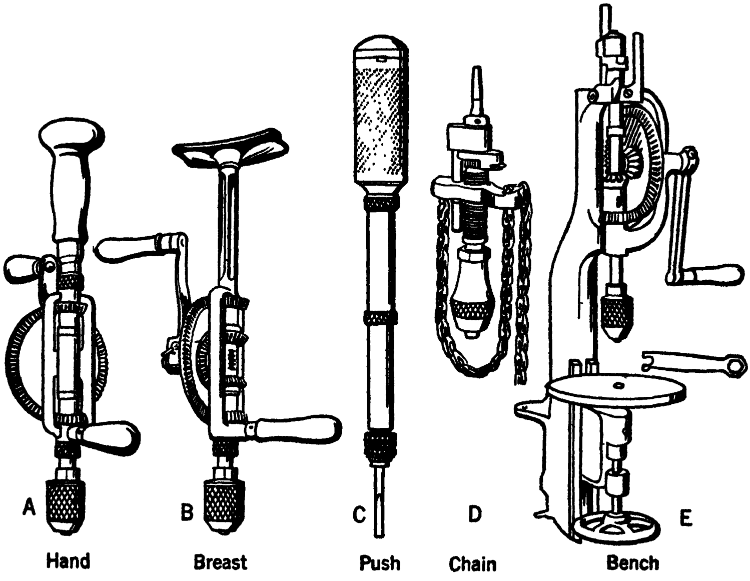


Fig. 5–11. Types of drills.

gear arrangement for slow and fast operations. In the *push drill,* the point is turned by the pressure of pushing the tool, not by turning a wheel or gear. (See Fig. 5–11*C*.) Drills may also be operated by power other than manpower. When the danger of electric sparks must be avoided, compressed air is sometimes used for power. But most often power drills are run by electricity. Such power drills relieve the mechanic of effort and make it possible to do more accurate work. The *automatic chain drill* is used with the common brace, but it has a chain attachment for applying pressure. (See Fig. 5–11*D*.) The *bench drill* is similar to a drill press, but it is operated by hand power. (See Fig. 5–11*E*.) Power drills that can be used only when the work is brought to them are called drill presses.

1. CENTER-PUNCH MARKING

The purpose of center punching is twofold: (1) to locate permanently the center of the hole that is to be drilled, and (2) to make a slight depression to provide a start for the drill point. If a punch mark is not made, the drill point will slip or "walk," and make the hole in a wrong location. Reference to punches was made on pages 242–243.

Unless great accuracy is required in locating the center of the hole (as in matching the holes with other holes or with fixed studs), approximate layouts with a chalk pencil and a steel rule are ordinarily accurate enough.

Figure 5–12 shows the procedure when special accuracy is required. As explained on page 243, put a thin layer of copper on the surface of the metal. Scribe two or more lines crossing at the spot where the center of the intended hole is located. Place a center punch exactly at the point of crossing. Then gently tap the center punch with a hammer. Use a magnifying glass if necessary to check the location of this punch mark. (See Fig. 5–12*A*.)

If the location is correct, scribe a circle with a pair of dividers, the diameter equal to that of the hole, as in Figure 5–12*B*. With

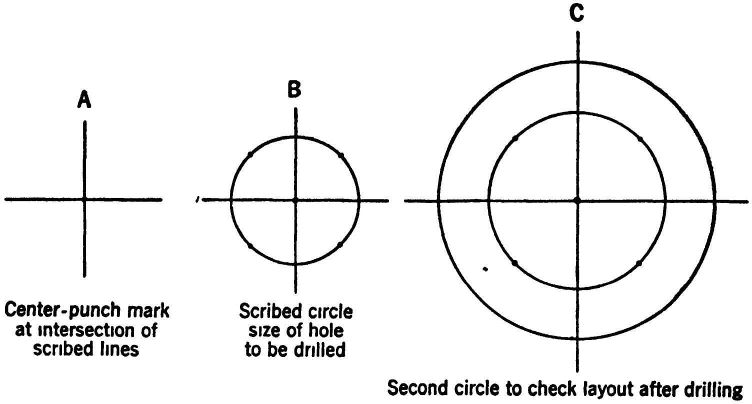

A
B
C
Center-punch mark at intersection of scribed lines
Scribed circle size of hole to be drilled
Second circle to check layout after drilling

FIG. 5–12. Layout for accurate drilling.

the center punch, make small indentations, called "witness marks," on the circumference of the circle. If a check is required after the hole has been drilled to see if the layout was followed, a second circle should be scribed outside the first one, as in Figure 5–12*C*.

As a last step in punching, use a center punch with a heavy blow of the hammer to mark the center of the hole to be drilled. If this broad, deep punch mark were made before the circles were scribed, it would be impossible to scribe these circles accurately.

Correcting punch marks. If a punch mark is incorrectly placed, perhaps about $\frac{1}{16}''$ off, replace the punch in the wrong punch mark. Slant the punch, pointing it in the direction of the correct location. Gently tap the end of the punch to move it along until the proper spot is reached, then move the punch to a perpendicular position and make a punch mark as explained on page 260.

If the incorrect punch mark is off more than $\frac{1}{16}''$, ignore it and make a new punch mark at the correct spot. To avoid confusion and error, the incorrect punch mark should be erased by gently tapping the metal back into the depression with the peen-ball hammer or with a round-pointed punch.

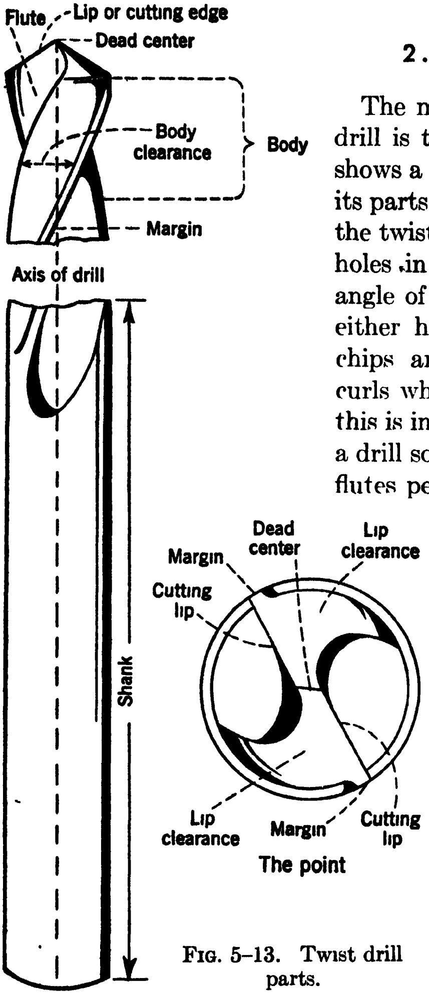


FIG. 5-13. Twist drill parts.

2. TWIST DRILLING

The most commonly used type of drill is the twist drill. Figure 5-13 shows a twist drill with its flutes and its parts named. For several reasons, the twist drill is excellent for drilling holes in almost any material. The angle of the lips can be varied to cut either hard or soft materials. The chips are removed in the form of curls which occupy very little space; this is important, for waste may jam a drill so that it cannot rotate. The flutes permit these curls to come out readily and make it possible for the lubricant to flow readily over all parts of the drill point.

Figure 5-14 shows the various types of shanks twist drills may have. The straight shank is intended to be held by the three-jaw chuck of the hand drill or breast drill. The *chuck* is that part of the machine that holds the drill. The square-shank (or square-tang) twist drill is planned to fit the two-jaw chuck of a brace, as a wood bit does. The tapered-shank twist drill is intended to fit the chuck of a drill press, lathe, or similar machine.

Twist drills come in a great variety of sizes, or diameters. There are three *series*, and no drill of any one series has the same

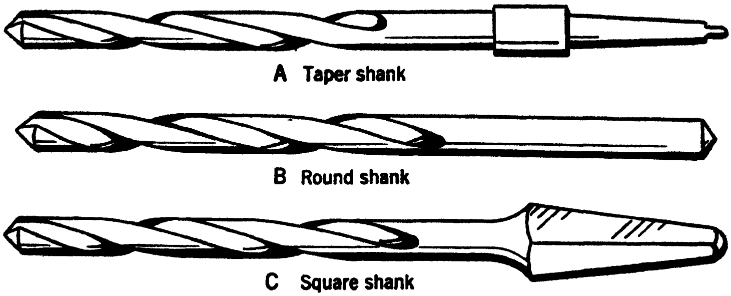


FIG. 5-14. Twist drills.

size as any drill in any other series. One series is numbered from 1 (which is 0.288 inch) to 80 (0.0135 inch) in diameter. Another series begins with $\frac{1}{64}''$ and increases in steps of $\frac{1}{64}''$ up to $\frac{1}{2}''$ diameter. Still another series is sized by letters from *A*, 0.234″, to *Z*, 0.413″. Table 7 in Appendix A combines all three systems of sizing into one, showing diameters in order from the largest to the smallest.

Sizes of larger drills are stamped on the shank. Since there is no room on the shanks of the smaller drills to stamp the size, it is determined by fitting the drill into the hole of a drill gage or by using a micrometer and the table of drill sizes.

A hole 1″ or less in diameter is generally called a *drill.* A hole larger than 1″ in diameter is commonly called a *bore.* However, standard drills are made up to $3\frac{1}{2}''$ in diameter.

Selection of drill size. The particular drill must be selected to make a hole of the required size. Whether the hole to be drilled should be threaded or unthreaded also determines the drill to use. If it is to be threaded, refer to Table 9, Appendix A to decide the size drill to use for a particular size screw. If it is to be unthreaded, refer to Table 7, Appendix A.

Determining drill speed. Speed is the rate (revolutions per minute) at which a drill turns. When holes are being drilled in certain materials, such as steel, wrought iron, and hard cast iron, the cutting speed and the life of the twist drill will be increased if a lubricant is used. Its chief purpose is to keep the cutting surface of the drill cool and thus keep its temper. Any light machine oil, kerosene, lard oil, cutting oil, or turpentine will serve, but heavy bearing oil should never be used. Cast iron, bronze, brass, and bakelite should be drilled dry. Kerosene is a good lubricant for drilling aluminum.

Carbon-steel drills, very low in cost, are used for ordinary work, especially in hand or breast drills. If used with high speed they *burn*, or lose their temper, and soften. High-speed drills, as their name indicates, are used for fast production work, especially as power drills.

When using a hand drill there is no need to consider speed, because the drill cannot be turned fast enough to cause trouble. It is when using power drills that the mechanic must be on his guard. Examples of proper speeds are: hard steel, 350 rpm (revolutions per minute); cast iron, 532 rpm; brass, 912 rpm.

The mechanic should always follow three speed rules: (1) The harder the material, the slower the speed. (2) The larger the drill, the slower the speed. (3) Always run the drill slow enough so that the heat of friction will be less than enough to reduce the temper of the drill.

Feed pressure. The feed is the rate at which the drill moves into the stock. Naturally this depends partly on the speed the drill is turning, but mainly on the amount of pressure applied on the drill. Therefore we are more concerned about feed pressure as it relates to power drills than as it relates to hand drills.

The feed depends on (1) the hardness of the metal, (2) the depth of the cut, (3) the lubricant used, (4) the size of the drill, (5) the kind of drill, carbon-steel or high-speed, and (6) the type of machine, hand or power. Speed and pressure should vary as the hole is drilled. Begin slowly with little pressure; end in the same manner so that the drill point does not suddenly push through the metal.

Since experience is the best guide, only one general rule can be given for feed pressure: Keep just enough pressure for the drill to remove material.

When the drill is to be taken out of the hole, keep it turning in a cutting direction but reverse the feed pressure; that is, pull instead of press on the drill until it is completely out of the hole.

There is a table of suggested speed and feed for high-speed steel drills in Table 8, Appendix A. This table is based on the experience of industry. The footnote explains how to figure the same information for carbon-steel drills.

3. COUNTERSINKING

The underneath part of the head of a flathead screw slopes at an angle of 82°. The beginning of a drill hole to receive such a screw must be finished with a similar slope. The procedure in doing this is explained in detail on pages 167–170.

4. SHARPENING DRILLS

Whether they are carbon-steel or high-speed, or whether they were used to cut soft or hard materials, drills will get dull with use. Since 90 per cent of all drill failures arise because of poor grinding, the mechanic should quickly master the skill of proper sharpening.

Figure 5–15 shows how a drill should be ground for general purposes. However, certain materials require different cutting

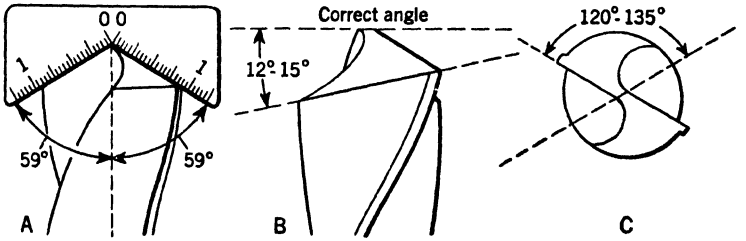


FIG. 5–15. For ordinary use, the angle of the lips and the center line of the drill should be 59°. Both lips should be equal in length, *A*; grind lip clearance correct, *B*; correct angle between line across dead center and edge of cutting lip, *C*.

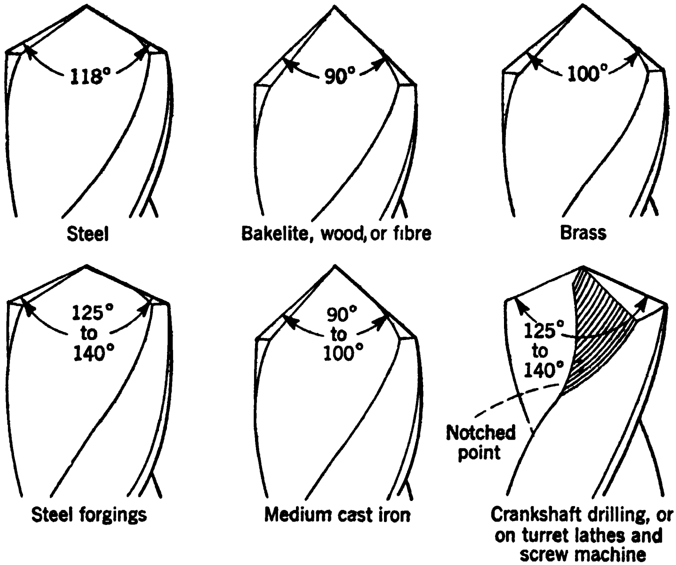


FIG. 5–16. Grinding a drill for special purposes.

angles. Figure 5–16 shows how the drill should be ground for special purposes.

It is no simple matter to sharpen a drill correctly. A special drill-grinding attachment is low in cost and should be used. When possible, drills should be ground on a power grinder, not on a hand grinder. However, care must be taken not to burn the drill. When grinding a carbon-steel drill, dip it frequently in water to keep its heat below that of its temper. Always check the cutting angles of a sharpened drill with a drill gage.

5. USE OF DRILLS

Most of what has already been said about drilling applies to hand drilling. The following is a summary, with some additional suggestions. (1) Locate the center of the hole to be drilled. Make a punch mark on it.

(2) Select the proper size drill to make a hole of the required diameter. Make sure that the cutting edge is sharp and properly ground.

(3) If the work is not attached to a rigid object, it must be placed in a vise or some other device to hold it securely while drilling. If the object to be drilled is clamped to the work table, place a piece of waste lumber under it to receive the drill after it penetrates. This will protect the table top and the drill point. If blocks are supporting the work do not have them too far apart. This will cause springiness of the work and may possibly snap the drill.

(4) Insert the drill in the chuck. Make sure that the end of the shank is at the bottom of the chuck. If only the end of the drill is held by the chuck, the strain may be enough to break the drill or damage the machine.

(5) Place the drill point in the center-punch mark. Sight along two directions at right angles to each other to make sure that the drill is at right angles to the work.

(6) Do not change the angle of the drill after part of the hole has been drilled. Keep the drill steady; otherwise it may break.

(7) Turn the handle as rapidly as possible. Keep feed pressure steady and just enough to keep cutting. Too much pressure may break the drill.

(8) If the hole is to be cut through, be careful that the drill does not go through suddenly and thus break. If the hole is not to go through, remove the drill once in a while to check for depth. If fine accuracy is required, use a depth gage.

Portable electric drills. Portable drills are made in a great many different types. However, they may be classified as light-duty and heavy-duty drills. Light drills take points up to ¼″ in diameter and generally have a pistol grip. Heavy drills take points up to 1″, are quite heavy, and have an extra handle to hold the machine steady. Ordinary straight-shank drills are used, as in the hand drill. The size of the drill is given as the largest size drill it will hold.

Cheap, light, portable drills have the same chuck as the hand drill, the type that is tightened with the fingers. Better light drills and most heavy drills have the chuck that must be tightened with a key. This kind is best and safest because it allows for a tight grip on the drill point.

In addition to these special points of information, all the previous advice about drilling by hand applies here as well.

Drill press. In addition to the general instruction already given, the following applies particularly to the use of the drill press. Before putting on the power, check for certain things. The drill point is brought to the work by pushing down a lever. Check to see if the drill will reach the work. If it does not, the clamp knob holding the table in place should be loosened, the table raised to the correct height, and the knob tightened again.

If the hole is to be drilled only part-way through the work, the stop gage for feeding the drill should be checked. If the hole is to go through the work, the drill point should reach just a trifle beyond. A piece of wood should be placed between the work and the table, or the hole or slot in the table should be properly aligned with the drill. The purpose in either case is to prevent the table from being marred with drill cuts.

Pressure on the drill is controlled by the feed handle. Some machines, though, have automatic feeds. Usually speed can be changed by changing the belt-and-pulley arrangement.

Small pieces should be held by pliers or clamped to the table in a vise. Otherwise there is danger of the work's spinning and causing damage or injury. The V-block is used on the table to hold round work, such as tubes and bars.

In the beginning just drill a small part of the hole and check to see whether it is located properly. If it is not, make a cut with a cold chisel, and move the work so that the drill hole will be properly placed. (See Fig. 5–17.) The chisel cut permits the drill to cut at the new spot without walking. If the hole to be drilled is large, first drill a small hole, about $\frac{3}{32}''$, as a pilot for the large drill.

Drive the tapered drill into the sleeve or socket by tapping it

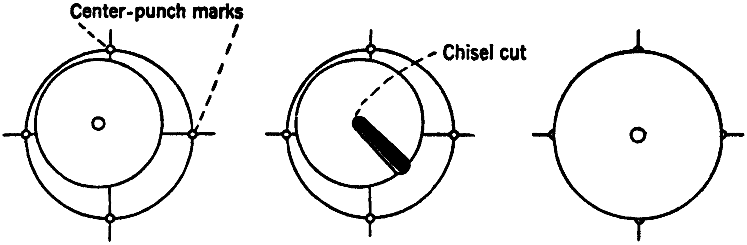


FIG 5–17. Drawing back drill to correct center.

with a soft-lead or brass hammer. Never hit it with a machinist's hammer or a piece of steel.

Do not use a file or wedge to pry out a drill from a sleeve or socket. Do not permit the drill when it comes out to strike the metal table. The correct procedure is to use a drill drift to "drift out" the drill and let it fall on a piece of wood or other soft material.

Oil the press as directed by the manufacturer's manual at least twice a day.

Emergency drilling. If no drill point is available and a hole must be made, a brad or nail of suitable gage can be substituted. It can be driven into the work and removed. The hole will not be accurate or smooth, but it may suffice temporarily.

Troubleshooting drilling faults. The tabulation on page 270 summarizes most troubles faced by drill-press operators, with the probable causes and remedy.

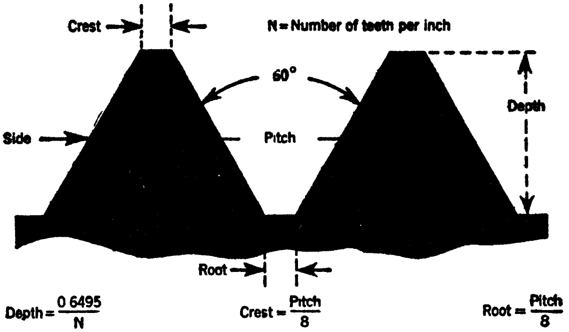
E. CUTTING THREADS

Nuts, bolts, screws, and studs are used for holding machine parts together or in place. All of these devices depend on threads. A *thread* is defined as a spiral ridge, uniform in size and shape, placed regularly on the outside or inside of a cylinder.

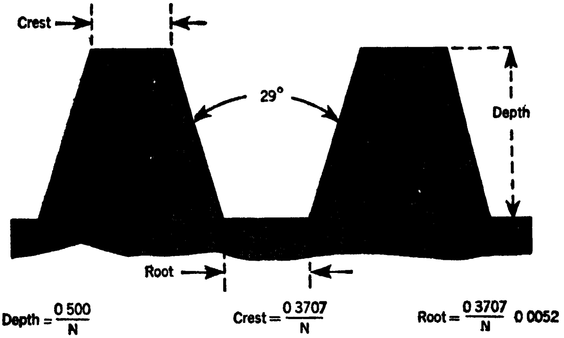
Threads can be cut by machine or by hand. Special machines are used for quantity production of threaded machine parts. For general requirements in a machine shop, a screw-cutting lathe is

DRILLING TROUBLES

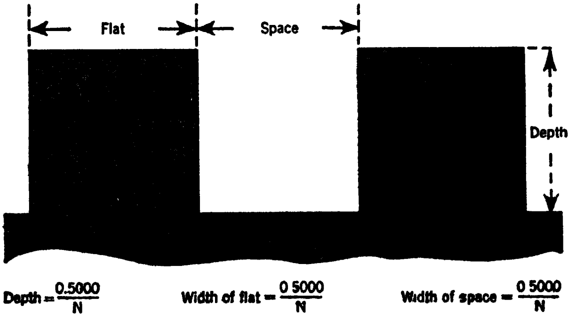
Trouble	Probable Cause	Remedy
Breaking of drill.	Spring or back lash in press or work. Too little lip clearance. Too low speed in proportion to the feed Dull drill.	Test press and work for rigidity and alignment. Regrind properly. Increase speed or decrease feed. Sharpen drill.
Breaking down of outer corners of cutting edges.	Material being drilled has hard spots, scale or sand inclusions. Too much speed. Improper cutting compound. No lubricant at point of drill.	Reduce speed. Use proper cutting compound and correct application.
Breaking of drill when drilling brass or wood.	Chips clog up flutes.	Increase speed. Use drills designed for these materials.
Broken tang.	Imperfect fit of taper shank in the socket — due to nicks, dirt, burrs, or worn socket.	Get a new socket or ream old one to prevent recurrence.
Chipping of margin.	Oversize jig bushing.	Use proper size bushing.
Chipping of lip or cutting edges.	Too much feed. Too much lip clearance.	Reduce feed. Regrind.
Chipping or checking of a high-speed drill.	Heated and cooled too quickly while grinding or while drilling. Too much feed.	Warm slowly before using. Do not throw cold water on hot drill. Reduce feed.
Hole too large.	Unequal angle or length of the cutting edges — or both. Loose spindles.	Regrind properly. Test spindle for rigidity.
Only one lip cutting.	Unequal length or angle of cutting lips or both.	Regrind drill properly.
Splitting up center.	Too little lip clearance. Too much feed.	Regrind with proper lip clearance. Reduce feed.
Rough hole.	Dull or improperly ground drill. Lack of lubricant or wrong lubricant. Improper set-up. Too much feed.	Regrind properly. Lubricate or change lubricant. Reduce feed.



American National thread



Acme thread



Square thread

FIG. 5-18. Thread forms and parts.

employed. By using taps and dies, threading can be done by hand. This is the means commonly used when the work cannot be brought to the machine, as when threading holes in a steel doorway to receive the screws that will hold the door hinges. In this section on cutting threads, we shall consider only the use of taps and dies.

It is not absolutely necessary for the mechanic to know all the terms and definitions of threading, but for reference the more important ones are included here. (See Figs. 5–18 and 5–19.)

Thread forms. The three commonly used forms of screw threads are: the American National, the acme, and the square. The American National is most common in motor-vehicle assembly. See pages 276–277 for more detailed information about this type.

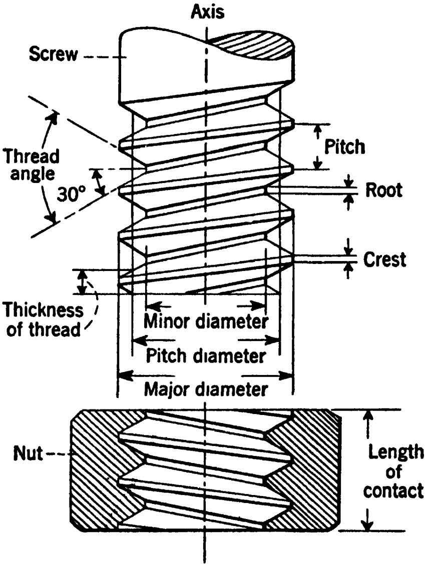


Fig. 5–19. Screw parts.

The *external*, or *male*, *thread* is on the outside of a machine part, as outside a pipe or rod end, or on a bolt or screw. The *internal*, or *female*, *thread* is on the inside of a machine part, as inside a pipe coupling or bolt nut.

Screw parts and measurements. *Major diameter*, sometimes called *outside diameter*, is the greatest diameter of a bolt or nut. It reaches from the top, or *crest*, of the threads on one side directly across the screw to the crest of the thread ridges on the other side. It is the diameter by which a screw, bolt, or nut is specified.

Minor diameter, sometimes called *root diameter*, is the smallest diameter of a bolt or nut. It reaches from the bottom, or *root*, of the threads on one side directly across to the root of the threads on the other side.

Pitch is the shortest distance from a point on the thread of a screw to a similar point on the next thread. Pitch in inches equals 1 divided by the number of threads per inch. Thus, if there are 4 threads per inch, pitch is $\frac{1}{4}''$.

Pitch diameter is the diameter of an imaginary cylinder which, if placed between the major and minor diameters of the screw, would so cut the threads that the thickness (not *depth*) of each thread at the point of cutting would equal the space between each pair of threads at the place of cutting.

Lead is the distance parallel to the length of the screw that a screw moves when given one complete turn. On a single-thread screw, the lead and pitch are the same; on a double-thread screw, the lead is twice the pitch; on a triple-thread screw the lead is three times the pitch, and so on.

Thread angle is the angle formed by the sides of the threads. It is 60° for the American National Screw; 29° for the acme thread.

Crest or *flat* is the top surface of a thread joining its two sides.

Root is the opposite of *crest;* it is the bottom surface joining the sides of two threads next to each other.

Side is the surface of a thread between the crest and root.

Axis is an imaginary line running in the center for the length of a screw.

Depth of thread is the distance between the crest and root of a thread measured perpendicular to the axis. It is half the difference between the major and minor diameters.

1. INTERNAL THREADING

Threads on the walls of drilled holes are made with a tap and tap wrench. (See Fig. 5–20.) *Taps* are made of highly tempered brittle tool steel, with square ends, or shanks, threaded and fluted for the distance of the threading. They look like screws that have three or four evenly spaced grooves cut across the threads along the length of the tap. These grooves or flutes make up the cutting edges By permitting the metal that was removed to come out, they prevent binding They reduce friction by presenting less surface than an unfluted screw would. And they permit lubrication to reach all parts of the tap and hole.

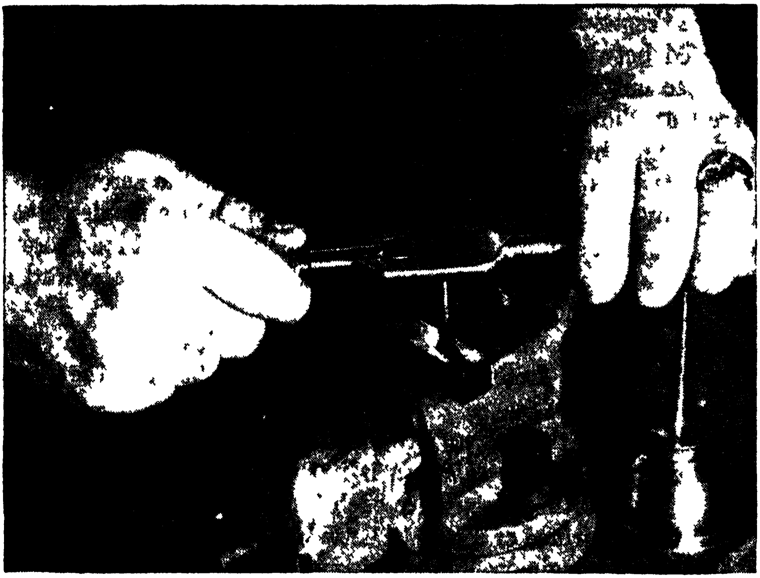


FIG 5–20. Threading a hole to receive a screw.

All taps have square shanks to permit the use of a wrench for turning them to cut the thread. Different tap wrenches are used for small and large taps. (See Figs 5–20 and 5–21) Each is adjustable to fit all taps in its class. Generally on the shank of each tap is stamped the manufacturer's name, diameter size of screw, number of teeth per inch, and the type or form of thread

There are three kinds of taps: taper, plug, and bottoming. The *taper tap* gradually and uniformly decreases in diameter from $\frac{1}{3}$ to $\frac{1}{2}$ the length of the threaded distance, the diameter being smallest at the beginning of the threading. (See Fig. 5–21*C*.) A taper tap

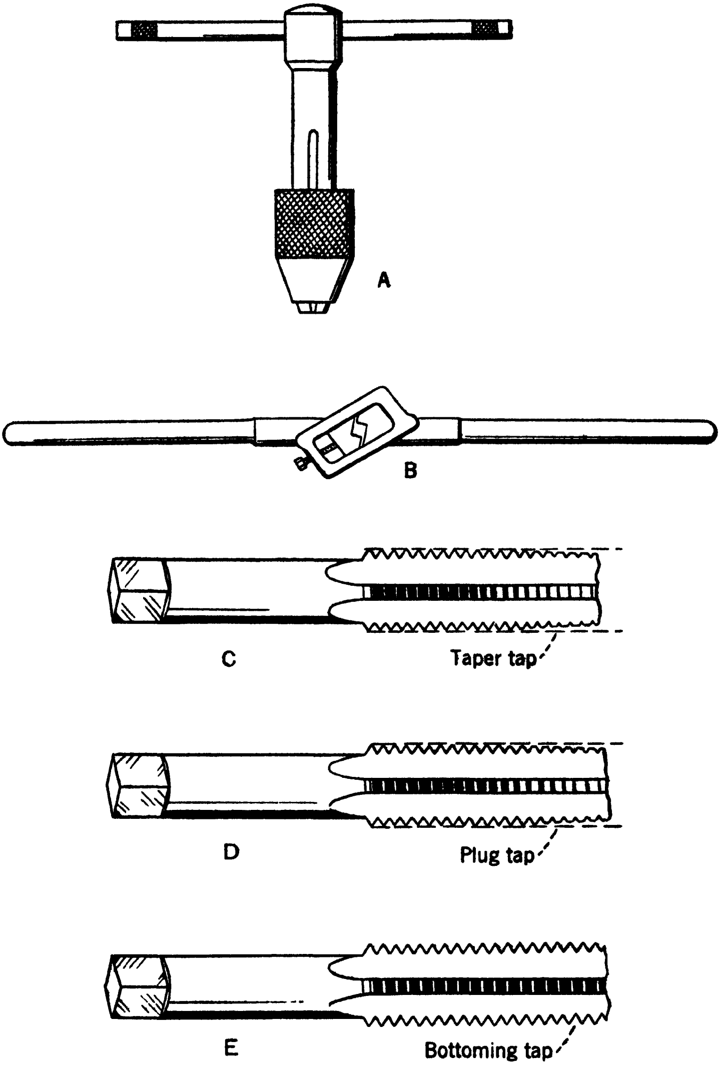


FIG. 5–21. Tap wrenches (*A* and *B*) and taps (*C*, *D*, and *E*).

is used to start all internal threading. However, since its upper part has full threads, it can be used to complete the job if it can be run through the work, such as sheet metal.

The *plug tap* gradually and uniformly decreases in diameter, like the taper tap, but for only one-fourth its threaded length. (See Fig. 5-21*D*.) It is never used to start a thread. After the taper tap starts the thread, it is backed out; then the threading is continued with the plug tap. The plug tap is used on holes that do not go through the work (blind holes) but where there is no need to thread to the bottom.

The *bottoming tap* has the same diameter throughout. (See Fig. 5–21*E*.) It is used to run threads to the bottom of a blind hole. The taper tap is used to begin the threading and then backed out. Then the plug tap is employed until it reaches the end, and it is backed out. Finally the bottoming tap is employed to complete the job. Naturally, the hole must be cleared of all cuttings before the bottoming tap reaches the bottom. If the material is soft, like brass and copper, the plug-tap operation may be omitted. In this case the threading consists of two steps.

Hole sizes. Taps cannot drill holes. For a tap to be used, a hole of the proper size must first be made. If the hole is too small, the extra pressure and friction of tightness may be so great that the tap will break because of the increased force needed to turn it. If the hole is too large, the threading will be very shallow. This will result in a weak union with the part that is to be screwed into the threaded hole. However, it should be understood that the hole drilled must be smaller in diameter than the required bolt or screw diameter.

Before drilling the hole, read the information stamped on the tap: diameter size, number of threads per inch, coarseness of thread, and type. With this information, consult a table such as Table 9, Appendix A, to find the size of drill to use for the particular hole. When a table is not available the following formulas will give approximately the correct size of the hole to drill for tapping: For National Coarse threads: Size of drill hole = Diameter of tap in inches $- \dfrac{.975}{\text{No. of threads per inch}}$.

For National Fine threads: $\dfrac{1.05}{\text{No. of threads per inch}}$. (See also pages 284–285.)

If the answer gives a drill hole that does not match a standard drill size, the next larger size in the drill table should be selected. (If the next smaller size is chosen, the hole may be too small and cause the tap to break.) These formulas are not based on a full-depth thread, but on a 75% thread, which is the depth used for commercial production work. It is only 5% less efficient than full-depth thread, but it is cut much more easily.

Steps in cutting internal threads. (1) If the work is movable, secure it in a vise or clamp.

(2) Make a hole the correct size, not too wide or too small. If the hole is blind (ends inside the material), make sure it is deep enough. If not, the accumulated chips at the bottom will cause the tap to bind and break. See pages 259–265 for information on how to drill a hole.

(3) Select the correct size taper tap. Make sure it is sharp, for dull taps break easily. They are not easily sharpened in the shop, for special machines are required for a good job.

(4) Mount the tap securely in the wrench. Be sure it is square with the work. If the chuck of the wrench is worn, it will cause faulty alignment.

(5) Place the taper tap in the hole, as far as it will go. Make sure that it is square with the work. Apply a little lubrication on the end of the tap, as in drilling.

(6) Turn the tap with a slight pressure for three or four revolutions clockwise. That is enough for it to take. After this it will cut its way without pressure. Remember that a tap is made of very brittle steel that has no "give" to it. Therefore, when subjected to side pressure, such as the slightest attempt to bend it, the tap will break.

(7) After the tapping is begun, check the tap in two directions with a square to see that it is perpendicular to the work. If it

is not off too much, back it out and retap while gently forcing it in the proper direction. If it is very much off, use a countersink to remove the poor threads or redrill the hole correctly to a larger diameter.

(8) After the threading has been begun with the taper tap, continue with the plug and bottoming taps, as explained on page 276.

(9) As the tapping proceeds, for every full turn of the tap, back it out for half a turn. This helps clear it of chips and prevents the tap from binding. Aluminum especially should be tapped this way.

(10) Don't back out a tap completely if it can be avoided, for every time it is backed out, small chips land in the thread grooves and cause extra wear on the tap and the threads already cut. This results in a thread that is not accurate. If the hole goes through, the tap should be continued through and out the other end. This avoids backing out.

(11) When finished, clean the taps thoroughly, removing all burs and chips. Immediately put the taps away with the same general precautions taken in storing drills and files.

Removing broken taps. If a tap breaks above the surface of the work, it can be simply removed by grasping it with a pair of pliers or a wrench and using this tool to back out the broken tap. However, if the tap breaks flush with the surface of the work, or below it, it is not so simple to remove. Several methods, though, are available.

Using a small, blunt, cold chisel or a taper punch, gently tap the edge of the tap in a backing-out direction. When it is loosened, a tap extractor can be used. The prongs of the extractor are small enough to fit into the flutes of the broken tap. The collar that holds these prongs is moved down flush to the work and set rigidly in place. Then a tap wrench is used to back out the broken piece.

Instead of using the tap extractor you may back the screw out a few more turns with the cold chisel or taper punch and then remove it as you would remove a tap that breaks above the surface of the work.

Or, you may break the tap further into smaller pieces with a solid punch and hammer. You can then pick out the pieces with a center punch or a magnetized scribe.

2. EXTERNAL THREADING

Threads on the outside of a rod or bolt blank are made with a die and stock. (See Fig. 5-22.) The die does the cutting; the stock holds the die and provides the needed leverage. The die may be adjusted and held in the stock by means of a *screw plate.*

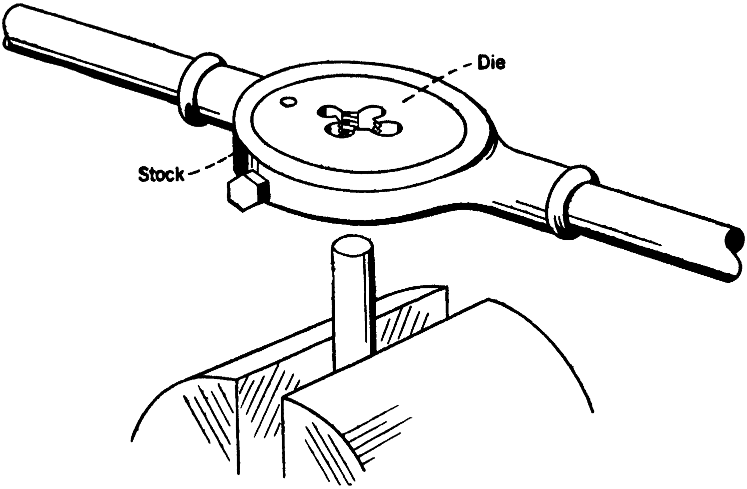


FIG. 5-22. Stock and die ready for use.

Dies are made of hardened tool steel, threaded like a nut but with four evenly spaced grooves cutting across the threads. As with taps, these flutes or grooves provide the cutting edges for removing metal. Also, they provide a path for the metal chips to come out, they reduce friction, and they allow for lubrication. To permit placing the die squarely on the work, the threads on one side of the die are of wider diameter than those on the other side.

Because thread terms and definitions apply to both inside and outside threads, dies agree with taps in diameter, pitch, coarseness of thread, and the like.

A *solid die* makes threads of just one size. In an *adjustable die*, however, there is an inset screw which regulates the size of the hole and therefore of the threads cut. An adjustable die is good to use when the material is a little off size or when looser or tighter fits are wanted.

As with taps, the die usually has the following information stamped on one face: manufacturer's name, diameter of screw, threads per inch, and coarseness and type of thread.

Steps in cutting external threads. (1) Cut the required length of rod, keeping the end at right angles to the length.

(2) Remove the hacksaw burs. Slightly bevel the end of the rod.

(3) Mount the work rigidly in a vise.

(4) Select the correct die. Be sure the die is clean of chips from the last job.

(5) Place the guide and die in the stock with the side of the die having the stamped information facing you.

(6) Place the guide over the rod, with the die resting on the end.

(7) Make sure that the stock is at right angles with the rod. This is the position in which it must be kept until the job is complete.

(8) As with the tap, keep the die lubricated; and for each full turn clockwise, back it up a half-turn until the job is completed.

(9) If the thread must extend up to a shoulder or some other projection, remove the die, reverse it, replace it, and complete the last few threads.

(10) Clean stock and die and put them away promptly.

Pipe threads are cut in a similar fashion. The last few threads taper to provide a tight, leakproof fit.

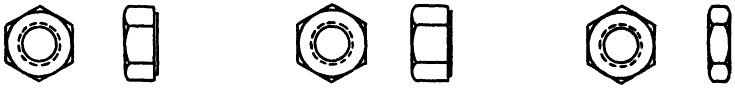
F. SHAPES AND SIZES OF NUTS AND BOLTS

Very often the mechanic must join two pieces of metal. Soldering, bolting or screwing, and riveting are the most common methods. First we shall study nuts, bolts, screws, and rivets. We shall consider soldering in detail in a later section.

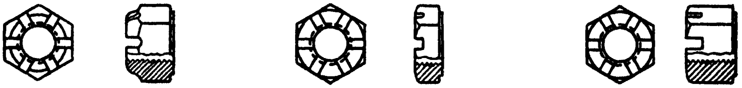
1. NUTS

A nut is a small piece of metal drilled with a hole threaded to match the threads of a bolt, screw, or stud. If the thread of the nut does not fit that of the bolt, the teeth will be jammed or stripped. Nuts, like bolts, screws, and studs, are made of a variety of metals, such as steel, aluminum alloy, brass, and the like, and may be plated with rust-preventing metals such as copper and cadmium.

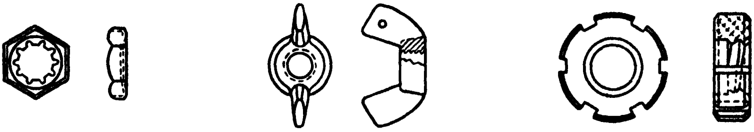
Kinds of nuts. Figure 5–23 illustrates the various kinds of nuts used on machines and in the sheet-metal and aviation industries.



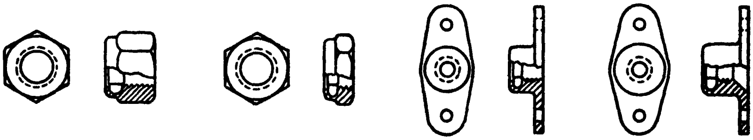
A Plain nut B Plain engine nut C Check nut



D Castle nut E Shear nut F Slotted engine nut



G Lock nut H Wing nut I Coupling nut



Thick Thin Plate Plate-countersunk

J Self-locking nuts

Fig. 5–23. Common nut types.

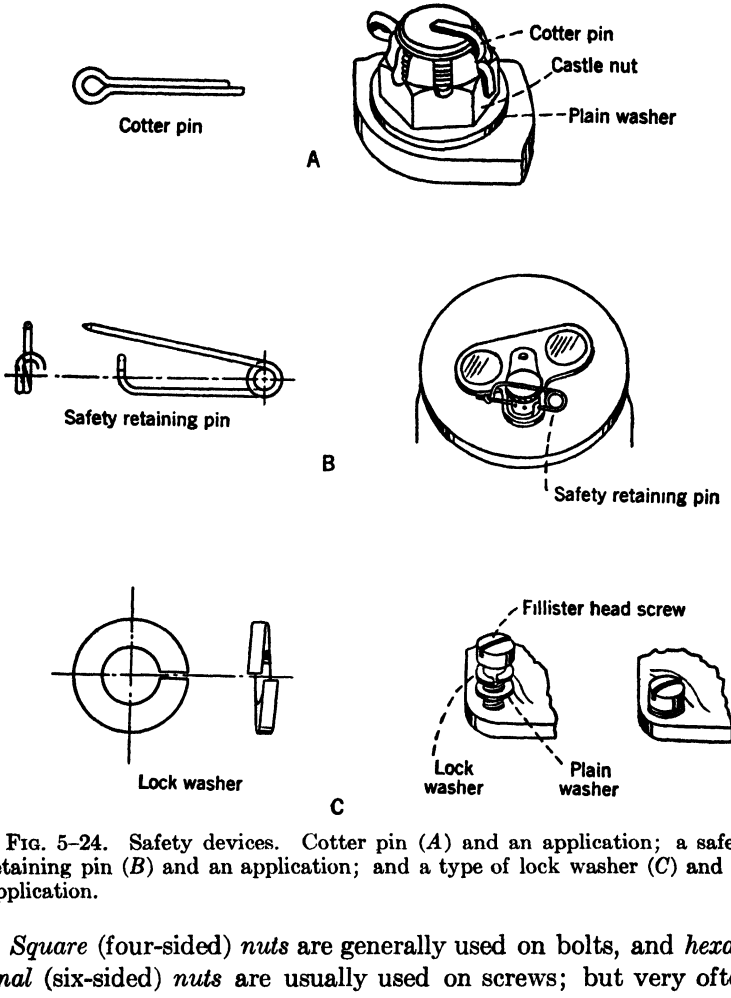


FIG. 5–24. Safety devices. Cotter pin (*A*) and an application; a safety retaining pin (*B*) and an application; and a type of lock washer (*C*) and an application.

Square (four-sided) *nuts* are generally used on bolts, and *hexagonal* (six-sided) *nuts* are usually used on screws; but very often they are interchanged.

There are a number of safety devices used in connection with nuts. Figure 5–24 shows three of these and some of their uses.

The *check nut* is used with plain nuts and set screws as a locking device to prevent the plain nuts from unscrewing and dropping off.

The *castle nut, shear nut,* and *slotted engine nut* all require a drilled hole in the bolt or stud. A cotter pin is inserted in this bolt hole to prevent the nut from coming off. The several slots on the nuts permit of proper adjustment of tension with correct alignment of slot and hole.

The *lock nut* is another type used with other nuts to prevent them from coming loose.

The *wing nut* is used where great tension is not required and, therefore, where the fingers can be used for tightening.

The *coupling nut* is used with a coupling (in electrical work) to join two sections of conduit or to join a conduit to a junction box.

There are several types of *self-locking nuts;* all are designed to provide a locking arrangement for the nut without the use of other aids.

Emergency substitutes. When unable to get a lock nut or washer, you can temporarily lock a nut to a screw by winding wire around the threads extending beyond the nut. As soon as possible, of course, the screw should be replaced and the correct lock nut or washer put on.

2. BOLTS

Bolts and screws are solid metal cylinders with heads; they are threaded to receive nuts or to be screwed into tapped (threaded) holes.

A *stud bolt* is threaded at both ends and therefore has no head. A blank space between the two sets of threads permits gripping the bolt with a pipe wrench. Usually one end is screwed into the main part of a machine and the other end protrudes through a hole in another part to receive a nut.

Bolts with nuts are used for holding together two or more separate pieces. Screws are generally used in tapped holes. However, the terms are interchangeable, for bolts can also be used in tapped holes and screws can be used with nuts.

Classification of bolts and screws. Bolts and screws are classified according to: (1) length, (2) type of head, (3) pitch, (4) diameter, and (5) material. (See Fig. 5–25.)

Length is the distance from the underside of the head to the end of the bolt. *Type of head* is the shape of the head, which may be hexagonal (six-sided), square (four-sided), round, flat, and so on. *Pitch* consists of the number of threads per inch or the distance from a point on one thread to a similar point on an adjacent thread. *Diameter* is the maximum distance across the bolt or the distance across the cylinder before the thread is cut. The *material*, as with nuts, may be steel, brass, bronze, aluminum alloy, and the like, or rustproofed with a plating of a rust-preventing metal such as copper or cadmium.

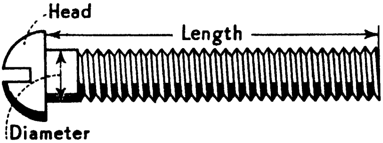


FIG. 5–25. Parts of a screw.

Threads. The more common forms of screw threads are called National Coarse series, National Fine series, National Extra-fine series, and American National Taper Pipe Thread.

The *coarse-thread series* is used with soft metals and in designs where rapid engagement is wanted.

The *fine-thread series* is used in general in aircraft and engine construction. It is widely applied to fastenings such as bolts, screws, and turnbuckles. Since this series has more threads per inch than the coarse series, the engagement is not so rapid. Further, since the threads are not cut so deep as in the coarse series, the fine series is stronger.

The *extra-fine thread series* is used where thin-walled material is to be threaded, where the depth of the teeth must be kept to a minimum, and where a maximum number of threads per inch is wanted.

The *pipe thread* is used on taper-threaded pipe joints, the taper ($\frac{3}{4}''$ per foot) permitting a tighter fit with continued engagement of the screw thread.

Usually National Fine is expressed with the letters NF, and National Coarse with the letters NC.

Screws are also designated according to the number of threads per inch and the major diameter of the screw. Thus, size 1–8–NC means one-inch diameter, eight threads per inch, with National Coarse thread. Screws of a diameter smaller than $\frac{1}{4}''$ are designated by gage number instead of inch size. Thus 10–24 means 24 threads per inch on a cylinder that gages 10.

Screw threads are also designated by fit, as loose fit, free fit, medium fit, and close fit. NF–3 means National Fine medium fit. Threads are generally right-hand, designated *RH*. When left-hand, they are marked *LH*.

Pitch can be measured with a steel scale or with a pitch gage, shown in Figure 5–26.

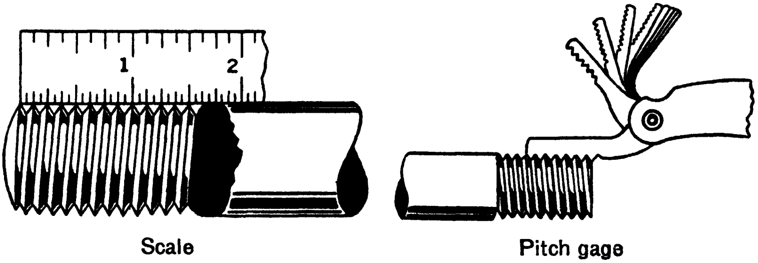


FIG. 5–26. A screw pitch gage.

Kinds of bolts and screws. Figure 5–27 illustrates the kinds of bolts and Figure 5–28 the kinds of screws commonly used by the machinist. In addition to the heads shown, machine screws and bolts come with special screwdriver slots, such as the Phillips, already considered in Unit IV, Woodworking. In addition to these, the sheet-metal and airplane industries use other types of screws, shown in Figure 5–29, and bolts, shown in Figure 5–30.

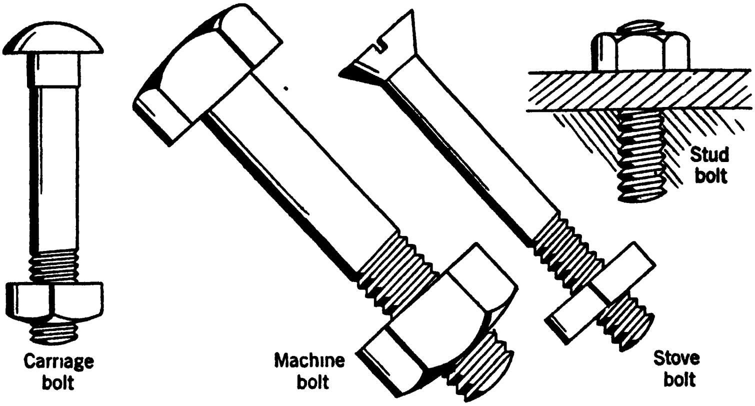


FIG. 5–27. Types of bolts.

The *flathead screw* requires a countersunk hole. This provides a surface free from protrusions and aids in streamlining.

The *roundhead*, *buttonhead*, and *washerhead screws* are used where projections are unimportant. They require no countersinking The washerhead is especially good in providing a large contact area.

The *fillister-head screw*, coming with or without drilled head, is generally used in light-mechanism assemblies.

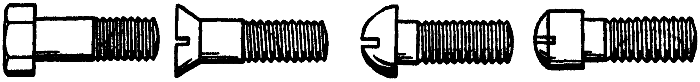
Machine and *cap screws*, being used most often without nuts, require threaded holes.

Set screws are used for holding wheels, knobs, or collars rigidly in place on shafts. *Socket-type* set screws are turned by inserting a wrench made of hexagonal hardened steel into the head of the screw.

Lag screws are used for attaching metal to wood, as a vise to the work table.

Sheet-metal screws, made of case-hardened steel, can make their own threads when screwed into a tapped or punched hole. They do away with the need for tapping the hole or using a nut. One type resembles a wood screw; another resembles a machine screw.

The *drive screw*, also made of hardened steel, is designed for being driven into an untapped hole of a diameter slightly smaller



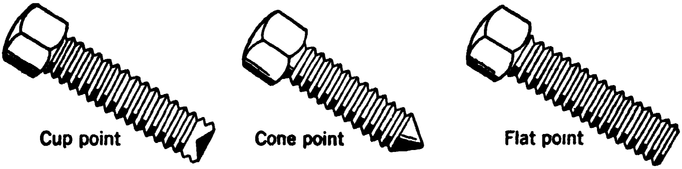
Hexagon head

Flathead

Buttonhead

Fillister-head

Cap screws

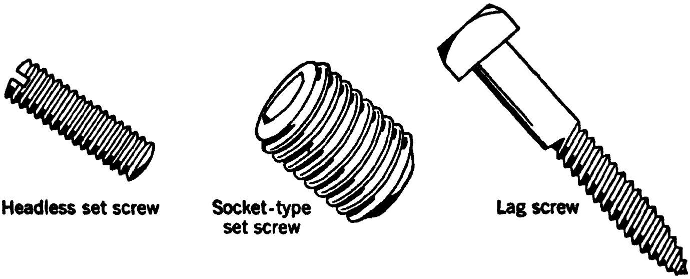


Cup point

Cone point

Flat point

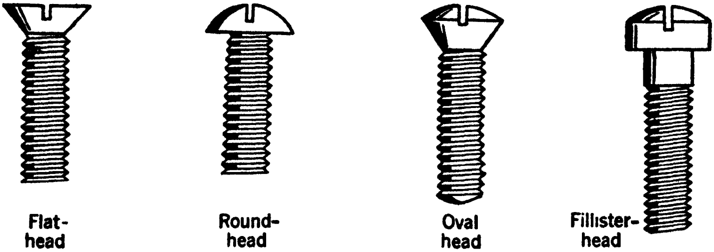
Square-head set screws



Headless set screw

Socket-type set screw

Lag screw



Flat-head

Round-head

Oval head

Fillister-head

Machine screws

Fig. 5–28. Types of screws.

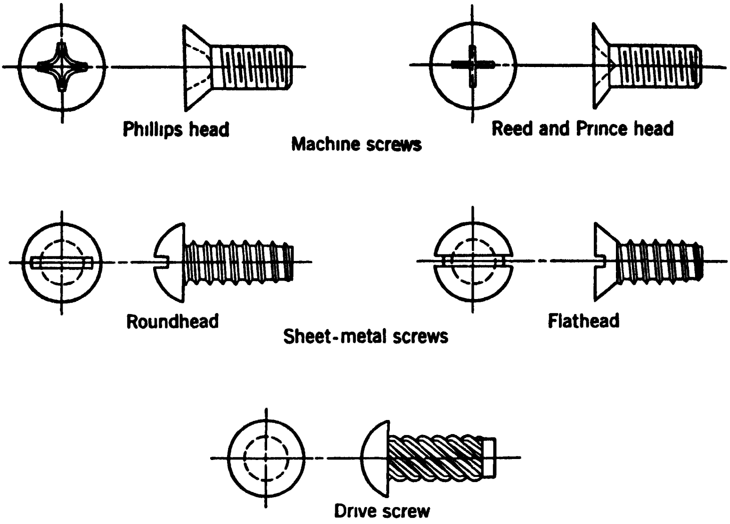


FIG 5-29 Sheet-metal and airplane screws.

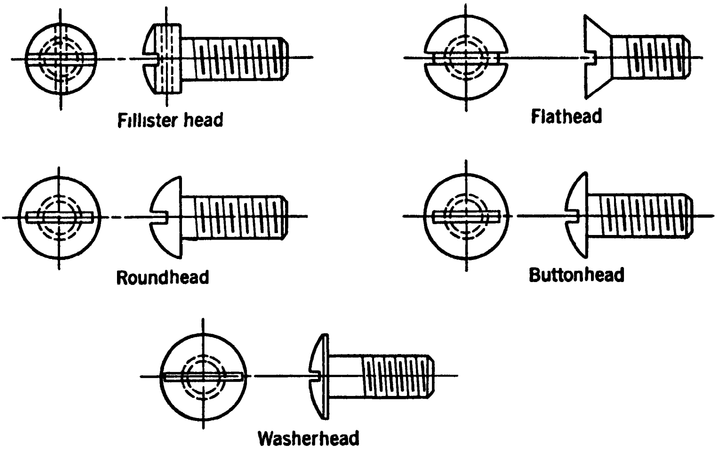


FIG 5-30 Airplane bolts.

than that of the screw. It is chiefly used for plugging holes and attaching name plates.

Washers. These are discs of metal used with screws, studs, bolts, and nuts to protect the surface of the metal, to provide a larger clamping area, or to keep nuts or bolts from loosening. (See Fig. 5–24.)

3. USE OF CATALOG TABLES FOR DRILL AND TAP SIZES

When a hole must be drilled and then tapped to receive a screw, the mechanic must know what size hole to drill and what size tap to use. This information, for screws of all sizes, is given in Table 9, Appendix A.

Counterboring and countersinking. Sometimes a hole must be enlarged for part of its depth to receive the head of a screw so that it will be flush with the surface of the metal into which the screw is turned.

If the underneath surface of the screw is at an angle with its shank, as in the flathead type, then the wider part of the hole must have sloping or tapered sides. For this a countersink is used. The three-flute countersink with a round shank is used in a drill. The rose type, with a square insert, is used in a regular brace.

If the head of the screw has parallel sides, as in the fillister type, the sides of the widened part of the hole must be parallel. For this a counterbore is used. The pilot of the counterbore fits the original hole and leads the cutting edges of the counterbore to widen the hole. Counterbores come in various sizes to fit various holes.

4. RIVETING

Rivets are used when two materials, especially metals, are to be joined permanently, that is, when there will never be the need to take apart the assembly and then reassemble it.

Kinds of rivets. Rivets are made in a great variety of heads, shanks, and metals. Some large steel rivets must be applied in a red-hot state when used to hold together the great steel girders of buildings and bridges and the heavy steel plates of ship hulls. Others, extremely small in size, are used in such fine industries as jewelry-making and watch manufacturing.

We shall consider here only rivets used for ordinary sheet-metal work, as in the aviation and radio industries.

Rivets are described according to: (1) *shank*, as solid, tubular, or special type such as Riv-Nut; (2) *metals*, as copper, aluminum alloy, soft steel, and the like; (3) *shape of head;* (4) *diameter of shank;* and (5) *length of shank. Solid shank* rivets are the type commonly used for most purposes in sheet-metal work. (See Fig. 5-31.)

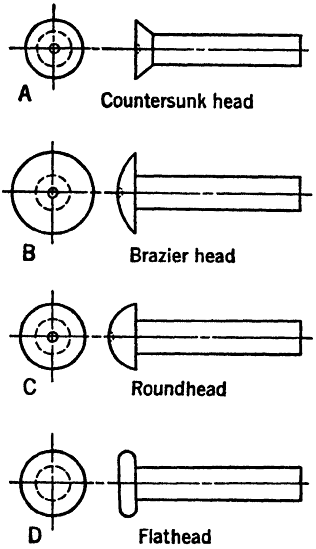


FIG. 5-31. Solid shank rivets.

Countersunk rivets are useful where streamlining is needed, as in airplanes. The countersinking is done as for bolts and screws. It permits the head of the rivet to be placed flush with the surface of the metal.

Roundhead rivets are used where a strong union is required but where the protrusion of the head causes no concern.

Flathead rivets are used in such constructions as fuel tanks.

Brazier-head rivets are used on certain external surfaces of aircraft and for patching.

Tubular shank rivets are shallow drilled for metals. For soft materials, like leather, they are deep drilled.

Riv-Nuts are made for use on surfaces that can be reached on only one side, as in certain places on the fuselage of a plane. (See Fig. 5-32.) Note that in ordinary riveting the mechanic must

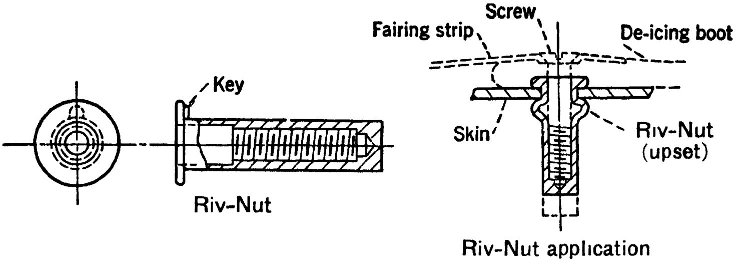


FIG. 5 32. Riv-Nut and an application.

be able to reach both sides of the metal at one time; holding the rivet in place on one side and upsetting it on the other side. Riv-Nuts are used for attaching de-icer boots on a plane and for similar purposes.

Explosive rivets are also made for places that can be reached only on one side or where there is insufficient room for the swing of the hammer in upsetting and heading. They look like solid-shank rivets, but near the end of the shank they contain an explosive charge. The rivet head is held in place and when the charge explodes, it swells out the end of the rivet as if it were upset by a hammer.

Sizes of rivets. Tinners' rivets are made of soft steel, coated with tin to prevent rusting. Sizes are given in ounces or pounds according to the weight of 1000 of the rivets. Thus, they may be 8 ounces (very small), 1 pound, or $1\frac{1}{2}$ pounds in size. Other kinds of soft-steel rivets are sized by diameter and length of shank, as $\frac{1}{8}'' \times \frac{1}{2}''$ or $\frac{1}{8}'' \times \frac{3}{4}''$.

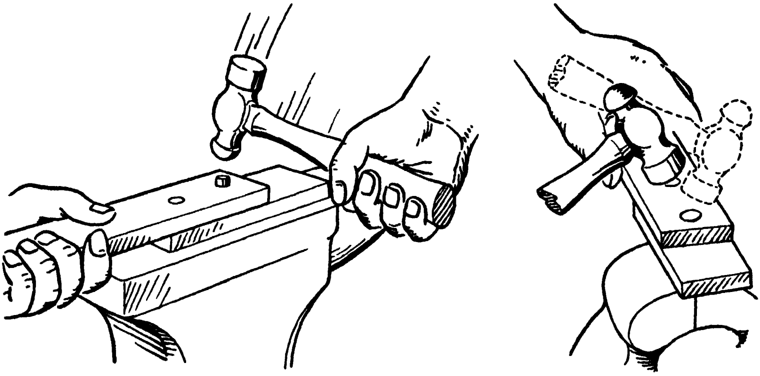
The length of all rivets except the flathead type is measured from the underside of the head to the end of the shank. The length of flathead rivets is over-all, that is, from the top of the head to the end of the shank.

Driving rivets. First properly locate and punch or drill the rivet holes in the work. Refer to Table 10, Appendix A, for drill sizes for rivets. Then decide on the proper type and size of rivet to be used. The length should equal the thickness of the stock plus

1½ times the diameter of the rivet. The diameter of the rivet should be just sufficient to fit the hole as perfectly as possible. If the rivet is not long enough, too little metal will protrude for driving. As a result, just a little strain will be enough to separate the metals that were intended to be held securely and permanently in place by the rivet.

A rivet is secured in place by upsetting the end of the shank, that is, by mushrooming or spreading out the end with a hammer. If too much of the shank protrudes the rivet will bend, a tight clamp will not be made, or both may happen.

Insert the rivet in the hole so that the head is under the work resting on a solid surface such as an anvil, stake, or riveting blank. Hold the pieces of metal together firmly. If this is not done after the rivet is upset and headed, it may be found that the two metals have separated just at the spot where they were supposed to be kept in close contact by the rivet.


A Upsetting

B Heading

FIG. 5-33. Steps in driving a rivet.

With a peen hammer, strike straight down on the rivet with a heavy blow. (See Fig. 5-33*A*.) Then strike three or four times more with heavy blows. This will expand the shank of the rivet so that it completely fills the hole. Form a head by striking the outer edges of the upset rivet end with glancing blows, gradually circling the rivet. The peen ball or the face of the hammer may be used for this. (See Fig. 5–33*B*.)

If the head must be formed to shape, a *rivet header*, or *rivet set*, should be used. Before peening the rivet end, the hole in the bottom of the rivet header is sometimes placed over the rivet and the header is struck with the hammer to force the pieces of metal together.

When riveting leather and similar soft materials, flathead copper rivets should be used. Burs should be placed over the end of these rivets before heading them.

A special tool is needed with Riv-Nuts. The tool is screwed on to the threaded part of the Riv-Nut; then compression is applied. This causes the Riv-Nut to bulge directly under the head. A key fitting into a slot cut into the metal on the underside of the head prevents the Riv-Nut from turning.

Removing rivets. Though rivets are used for permanent fastenings, sometimes they must be removed, as for repairs. Several methods are used.

(1) Place a center-punch mark in the exact center of the head of the rivet. With a drill of exactly the same diameter as the rivet, drill a hole completely through the rivet. If done accurately the shank of the rivet will have been cut away leaving just two thin rings on top and bottom. They can easily be brushed off.

(2) If the parts riveted together are made of steel, and are more than a quarter of an inch thick, the *shearing method* may be used. The chisel is held with one bevel pressed firmly against the surface of the plate and the edge of the chisel touching the rim of the rivet head. When the chisel is struck sharply it forces the head of the rivet along the plate in the direction of the blow. The chisel acts like one blade of a shears; the plate itself plays the part of the other blade. A few sharp blows should shear off the head. *Warning:* When a rivet is removed in this way, goggles must be worn. Care should be taken to see that no one passes or stands in the possible path of the rivet. Have your teacher check conditions before you strike the chisel. A flying rivet head can cause serious injury within a range of thirty feet.

(3) A safer method is to hold the chisel as described in instructions under method (2) and with a sharp blow curl up one edge of the rivet head. Then repeat the operation from a point opposite. In the space provided by the curling up of the head insert the jaws of a pair of end- or side-cutting nippers. Closing the nippers will snip off the head of the rivet. This is a safe and quick method.

This method is not approved for use with soft metals, as in the airplane industry, because of the possible damage to the work.

(4) File off the head of the rivet, taking care not to mar the surrounding metal.

In all three cases, after the head of the rivet has been removed, drive the rivet out with a tool called a driving punch. This tool resembles a center punch but has no point on its end. Instead, it is ground flat. The diameter of this flat end should be slightly less than the diameter of the rivet. Never use a center punch because the point will spread the shank of the rivet and lock it in the hole.

In double-countersunk rivets, both head and upset ends are flush with the surface. These rivets may be removed by cutting a slot similar to the slot in a screw. This slot may be cut in either the head or the upset end. To cut this slot, use a small cape chisel. The edge of this cape chisel should be as wide as or a little wider than the diameter of the shank of the rivet.

Start the cut at the approximate center of the rivet and cut toward one edge. Then, using the same starting point, make a cut reaching to the opposite edge. There will now be a high point in the slot, at the center. Chip this out and then deepen the slot until the shank of the rivet is reached. When this occurs what is left of the head will fall off. By using the drift punch the rivet may now be removed.

When a rivet works loose it may indicate faulty workmanship, material or design. Try to find the cause. Possibly some other part has loosened and overloaded the rivet. It is good practice to replace a loose rivet, and safety regulations generally require that this be done. But if necessary, a rivet can be tightened by repeating the process used in installing it. A center punch may be used to spread it and cause its shank to fill the hole if the sections it holds together are thin. Remember that for a good job the rivet should be replaced, because the treatment used in retightening may so weaken it that it cannot be relied upon.

5. EXTRACTING BROKEN SCREWS

At times the head of a bolt or screw will break off, as, for example, when too much strain is applied while tightening. Naturally the piece remaining in the threaded hole must be removed before it can be replaced with a good screw. There are several ways of removing a broken screw.

(1) If the screw is sticking out above the metal, a slot can be sawed on the broken end. For this a hacksaw with a double blade (to make a wide-enough slot) is used. It will be found easiest first to make a shallow groove in the broken screw with a knife-edge or triangular file. This will prevent the saw blades from slipping off and causing injury to the mechanic or damage to the metal. After the slot has been made, a screwdriver is used to remove the broken piece.

(2) In a similar situation, the broken screw can be unscrewed with a pair of pliers or a small pipe wrench.

(3) If the break is flush with the surface of the work, tapping the screw near its rim with a center punch and hammer, in the direction for unscrewing, may turn the screw a number of times sufficient to bring the broken edge above the surface. Then method (1) or (2) may be used to complete the job.

(4) If the screw or bolt is large in diameter and is broken off flush with the surface or below the surface of the work, a screw extractor may be used. This is a hard tapered screw with a steep, left-hand thread. A hole is drilled in the broken screw for about $\frac{1}{2}''$. The diameter of the hole depends on the size of the extractor used. The extractor is set in the hole and turned left, the direction in which the screw would normally come out. However, since the thread of the extractor is left-hand, this tends to wedge its tapered thread into the hole of the broken screw. Thus

wedged, it brings up the screw. The proper-size screw extractor must be used.

(5) If the screw is of small diameter, the drill originally used to make the hole should be used to drill through the broken screw. This must be done accurately. Then the original tap used for threading the hole should be used to retap the hole.

NOTE: If the screw is rusted into the hole, use a rust remover, penetrating oil, or kerosene before attempting to remove the screw.

G. ABRASIVES AND PRESERVATIVES

Various grades of sandpaper are used in the woodworking shop for forming wood and preparing its surface. In the same fashion the metalworker uses various grades of emery cloth and crocus cloth. All of these, sandpaper, emery cloth, and crocus cloth, are called abrasives. Sandpaper was discussed on pages 212–213.

1. EMERY CLOTH

Emery cloth is used for hard metals, such as iron and steel. It consists of powdered emery glued to a cloth much as sand is glued to paper. Depending on the fineness or coarseness of the emery particles, we have fine or coarse emery cloth. Fine emery cloth is numbered 000, 00, and 0, triple-0 being the finest. Medium grade, in similar order, is numbered ½, 1, 1½, and 2. The coarsest grades are numbered 2½ and 3. The last group is rarely used.

If the surface is very rough, a coarse emery cloth, like No. 2, is first used, preferably wrapped around a block or file. The work is finished with a fine cloth. For a good polish, No. 000 cloth is used. When lard oil or flour is used with emery cloth, an extremely fine polish is obtained.

2. CROCUS CLOTH

Crocus cloth consists of iron oxide (usually called rust) glued to cloth. It is a very fine abrasive and produces a high polish on such soft metals as aluminum, copper, and brass. A scratch is a good beginning for a defect or weakness in metal. Crocus cloth, being a fine abrasive, is used to a large extent in the airplane industry to take out scratches in metal and to provide a high polish. A coarse cloth cannot be used on soft metals because it makes scratches of its own instead of removing those that were there in the first place.

3. OTHER ABRASIVES

Wire brushes are manufactured in various sizes, and shapes, and of various fibers and metals. They are used for cleaning surfaces, brushing off rust scales, smoothing up rough castings, and the like.

Steel wool consists of tangled masses of long, thin, hairlike shreds of steel. The coarseness is graded according to the width of these steel slivers. Steel wool is used in polishing metal, removing paint, and general rough cleaning.

4. SAFETY IN USING ABRASIVES

(1) Do not use steel wool, emery, or carborundum around electrical machinery. These abrasives are conductors and may cause a short circuit. Especially beware of using any of these abrasives near the commutator of an electric motor.

(2) Be careful that none of these abrasives get into the gears and lubrication of machinery. They wear away metal, whereas the purpose of lubrication is to preserve and protect metal against extraordinary wear.

(3) Never use emery on soft metals. Particles of the emery may get imbedded in the metal, and it is difficult to remove them.

(4) Wear gloves to protect your hands when using an abrasive, particularly steel wool.

H. SOLDERING

We learned that two or more separate pieces of metal can be held together by clamping, riveting, using nuts and bolts, and the like. Soldering is another means of doing this. However, it employs a principle entirely different from that of any of the examples just listed. It consists of applying a melted alloy to two or more heated metals so that when the work cools the metals are joined together rigidly. A *soldering iron* or *soldering copper* is used for this purpose.

What is solder? How are the surfaces of the metals prepared for soldering? What are the means for applying heat to melt the solder and heat the metals? What are the steps in soldering? These are some of the questions that will be discussed here.

1. CLASSES OF SOLDER

In all soldering work, no matter what the metals are or the soldering alloys used, only the solder is melted. Thus, it is easily understood that all solders have a melting temperature lower than that of the metals they join. If not, the metal would melt before the solder could be used.

(When no solder is used but the neighboring surfaces of the metals themselves are melted and joined together on cooling, it is not soldering. It is *welding*. Welding is also an excellent means of joining metals together. Its chief difficulty is the great heat that is required and the fact that such heat is not easily obtained by the mechanic with just ordinary equipment.)

There are many varied combinations of metals used to make different solders. No one single combination can be used for every purpose or for soldering all metals. Special solders are needed for particular metals and for special purposes.

Soft solder is commonly a half-and-half mixture of tin and lead to which are added small amounts of other metals for various purposes.

Cadmium and bismuth lower the melting temperature of the solder. Most metals contract when cooled, but bismuth expands and helps make the solder fill a hole or depression better. Phosphorus in the form of phosphor-tin permits solder to flow more freely. Zinc and aluminum will do the reverse, that is, make the solder flow slowly. Lead is chiefly used because of its low melting point, 620.6° F., and its cheapness.

Grade A soft solder is the alloy commonly used. It contains a minimum of 49% tin, begins to melt at 360° F., and is a liquid at 415° F. Composed mainly of two soft metals, lead and tin, it is not a strong solder and should not be used on parts where the failure of the soldered joint might cause a death or accident, as in aircraft manufacture. Soft solder should not be used for attaching fittings or ribs to main structural members, fuselage joints, or control machinery. It should never be used for filling cracks or pits to produce a smooth-appearing finish, as on damaged automobile fenders.

Soft solder best satisfies the general requirements in sheet-metal seams and low-resistance electrical connections. This provides sufficient strength for the union. The solder is used only to make perfect contact between the two.

Hard solder is used where a very strong union is needed to resist strong or constant vibration, great pressure, heavy blows, and high temperatures. Generally the rule is that the higher the melting point the stronger the solder. Hard solder composed mainly of silver and other metals such as copper and zinc has a high melting temperature of from 1600° F. to 1825° F. Such high temperatures require exceptional heat as generated by an acetylene torch or a compressed-air blowtorch.

Another type of hard solder is called *spelter.* It consists of four parts of copper and one part of zinc in addition to very small quantities of other metals. Soldering with this alloy is commonly called *brazing.* It is excellent for copper, brass, and steel.

To do good work in hard soldering, much practice and skill are required. Soft steel is easier to use. We shall therefore devote the rest of this section to soft soldering.

Cleaning. As we shall see, soldering is a comparatively simple operation. However, if certain rules are not very carefully observed, the results are discouraging. One of the most important warnings is that the surfaces to be soldered must be absolutely clean — free of dirt, rust, corrosion, grease and oil, and tarnish.

To clean the metal surfaces shiny bright, you can rub them with emery cloth, sandpaper, steel wool, scraper, or file. (See Fig. 5–34.) All resulting dust must be carefully wiped away. Particular care must be taken to reach all corners and cracks. Electric wiring should be scraped with the back of the electrician's knife to make sure that all insulation has been cleaned from the wire preparatory to splicing and soldering it.

FIG. 5–34. Filing a metal surface clean.

2. FLUXES

The use of fluxes. The surface of the metal may be absolutely clean, but as soon as it is exposed and especially when it is heated, it unites readily with the oxygen of the air to form a tarnish or oxide. This thin chemical layer is enough to prevent the solder from joining the metal. Therefore, it is absolutely necessary (1) to keep the cleaned metal from being exposed to the air and (2) to remove the layer of oxide, if it already has one, the instant the solder touches the metal. One thing does both these jobs — a flux.

Just as there is no single solder that is good for all metals, so there is no single flux that is good for all metals.

Corrosive flux. Some fluxes eat away not only the oxide covering, but the metal as well. After such fluxes are used, the metal must be washed with water or a neutralizing chemical to remove every trace of the corrosive chemical. If this is not done, the soldering job may make a perfect union which later is broken easily by the neighboring metal being eaten away.

A commonly used corrosive flux that gives fine results with steel, brass, nickel, lead, stainless steel, zinc, and galvanized iron is diluted zinc chloride, also called "killed" muriatic acid. For dilution, zinc chloride should be mixed fifty-fifty with alcohol.

Zinc chloride is made by adding small pieces of zinc, a little at a time, to muriatic (hydrochloric) acid until the mixture stops bubbling. This is called a saturated solution and in this state is an excellent cleaner for the tough scale on cast iron, galvanized iron, and sheet steel. Great care should be taken that the mixture, as it bubbles and sputters, does not spatter the clothes or skin. The mixture should never be made near machines or tools because the escaping gases will eat away almost any metal they reach. Also, avoid breathing in these fumes, for they damage human tissue. The mixture should be made in an earthenware container. If made in a glass jar, it may break it because of the great heat that is generated. If made in a metal container, the acid may eat away the container too.

It is absolutely essential to wash all soldered parts where zinc chloride was used, to remove all traces of the corrosive chemical.

Borax is corrosive flux which is best for hard soldering and brazing; it is not suitable for soft soldering.

Sal ammoniac is a corrosive flux that is seldom used. As we shall see later, it can be used to advantage in tinning soldering coppers. The fumes from heated sal ammoniac are poisonous and should be avoided.

Noncorrosive flux. The use of a noncorrosive flux avoids the dangers of eating away the metal and breathing in poisonous fumes.

Rosin is the most commonly used noncorrosive flux for copper, bronze, tin, brass, and lead. It is the only flux that should be used for general electrical work, and in an alcoholic solution it is especially good for radio-set construction and repair. It comes in powder, paste, and liquid form. It can also be purchased in hollowed-wire solder, but care should be exercised to check it because such solder also comes with an acid core.

Tallow and stearine, waxes made from animal and some plant fats, are other noncorrosive fluxes; they are used mainly for soldering lead, tin, and aluminum.

3. SOLDERING COPPERS OR IRONS

Heat is needed: (1) to melt the solder and flux and (2) to raise the temperature of the metal to that of the melting point of the solder. The heat is commonly applied with a soldering copper, sometimes called a *soldering iron.* (See Fig. 5-35.) The soldering copper consists of: (1) a piece of copper, called a head or tip, attached to (2) an iron or steel rod with (3) a wooden handle by which to hold it without getting burned. The head is purposely forged from copper because that metal conducts and gives off heat readily.

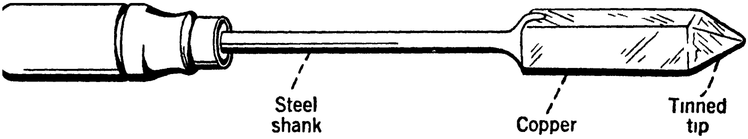
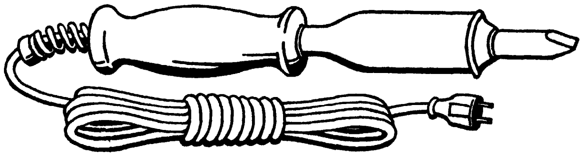


FIG. 5-35. A soldering copper.

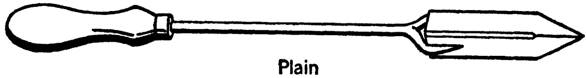
Externally heated. Some soldering coppers are heated from outside, by a torch, gas flame, or soldering furnace. Such a soldering copper cools as soon as it is removed from the flame and therefore must be constantly reheated. Where the soldering job is large, two soldering coppers are used, one being heated while the other one is melting the solder and heating the metals.

This type comes in a variety of shapes and sizes. They are rated by weight. The heavy coppers, because they can hold more heat, are used for large jobs.

Internally heated. Some coppers are heated from within by an electric current. (See Fig. 5-36.) This type employs the principle that when an electric current passes through a conductor



Electric



Plain

Fig. 5–36. Soldering coppers.

some of it is changed into heat. The amount of heat is proportional to the resistance. In the electric soldering copper a coil of high resistance wire, called the heating element, is contained within the copper. The heat produced in this coil passes to the tip and keeps it at the desired temperature.

In most cases the tip of the electric soldering copper is removable. At intervals of twenty to thirty hours of use, the tip should be removed and cleaned. If this is not done, the scale on the tip will accumulate and reduce the efficiency of the soldering copper.

Electric soldering coppers may be sized by weight, by the amount of power consumed, as 100 watts or 250 watts, or by the diameter of the copper points, as $\frac{3}{8}''$, $\frac{5}{8}''$, etc. They are more expensive to purchase and operate than the externally heated type. However, their use is most efficient for electrical and radio construction. They maintain a more constant temperature, save time in reheating, and do not burn off the tinning.

An electric soldering copper is a delicate instrument and should be treated as such. Never leave the current on too long while the copper is not being used. The tip may be overheated and the heating element burned out. Never clamp this type of copper in a vise in order to file the tip or make some other repair; to do so may damage the heating element. Do not expose the copper to sudden shocks or blows, for the heating element may become cracked. Do not take apart the electric copper unless you know what you are doing. Be careful of fires that can be started by carelessly resting an electric soldering copper against something combustible while the copper is hot.

Emergency substitutes. If a soldering job must be done and no soldering iron is available, a steel or brass rod can be used. It should be cleaned and tinned just as a soldering iron. Frequent reheating will be required. Be sure to protect your hand before picking up the rod, since these metals conduct heat rapidly.

Working temperatures. No soldering copper of any type should be heated to such an extent that the solder on its tip burns off. This occurs soon after the head becomes dark in the flame. It should be heated just enough to keep the solder flowing freely. Nor should the metal be heated so that it is much hotter than the melting temperature of the solder. If it is, the solder will remain liquid and possibly clump or even roll off.

Cleaning tip. A dirty soldering copper tip will result in a poor job, and may make soldering impossible. A soldering copper before being used must be tinned, and before it can be tinned it must first be cleaned.

To clean a tip, heat it and then file it with a mill file with strokes toward the point until the copper appears bright and all pitting is eliminated. Steel wool can be used to give a high polish.

To repoint the tip, forge it to shape. Heat the point until it is bright red, a temperature to which it should never normally be exposed. Forge it on an anvil with blows of equal force working on each face in succession. This prevents making the tip lopsided. The length of the taper should equal 1¼ times the thickness of the soldering copper body. When the correct shape has been achieved, the tip should be reheated again until bright red and then plunged into cold water. This is called annealing. It makes the copper soft again after being hardened by the blows during forging. It improves its radiating (giving-off-heat) qualities, too.

Before forging the tip from an electric soldering copper, it should be first removed from its holder. Be careful of burns from the splashing hot water or steam when the hot tip is plunged into the cold water.

Tinning. This is coating a surface, as the end of a soldering copper head, with a thin layer or film of clean solder. (See Fig. 5-37.) Every new soldering copper and every old one whose tinning is burned off, must be tinned. Tinning the tip makes it possible to transfer the heat effectively from the copper to the solder and metal. Also, it helps the melted solder to flow more smoothly and easily from the soldering copper to the metal. Then, again, small drops of solder that have fallen down can easily be picked up by a properly tinned and heated copper.

FIG. 5-37. Tinning an iron

Thoroughly clean the soldering end of the copper head, as already described. Heat this shiny surface until rainbow-like colors appear on it. This is a little above the melting temperature of solder. Rub each face of the head in a clean, shallow depression of a wood block into which solder and rosin have been melted. The rosin will act as a flux for making the solder stick to the copper.

Remove the surplus solder with a damp cloth. Note that only the soldering end of the tip should be tinned; not the entire tip. Also, observe that in an electric soldering copper the end of only one face should be tinned, not all four faces as with an externally heated copper.

Instead of the wood block and rosin, a brick of ammonium chloride (sal ammoniac) can be used. However, since the fumes given off are poisonous and corrosive, care should be taken not to breathe them in. Place a few drops of solder on the sal ammoniac and rub each face once or twice across the solder and sal ammoniac.

4. THE BLOWTORCH

In a shop where soldering is done more or less frequently and where gas is available, a small gas-flame furnace is usually set up to heat the soldering copper. However, where gas is not available and in cases where the soldering equipment must be brought to the job rather than the job to the shop, a charcoal furnace or a gasoline blowtorch is used.

Fuel. Naturally, the fuel for a gasoline blowtorch is gasoline, but it is not the leaded or Ethyl type that is used as a power source for automobiles. Lead is a poison that cannot normally be removed from the body once it has entered. It can enter in small amounts with food, through breathing, or through absorption by the skin. Eventually the deposits in the body may build up to so great an amount that the mechanic suffers the terrible effects of lead poisoning. Therefore, in using gasoline for any purpose other than power for automobile or aviation engines, always be sure that it is the plain or unleaded type.

(There are other kinds of torches besides the gasoline blowtorch. Electricians often use an alcohol blowtorch, which uses alcohol for fuel. Since it works automatically, all the details and cares of operation required for the gasoline type are unnecessary in using the alcohol type.)

To fill the gasoline tank with fuel, first turn off the jet valve. This is done by turning it in a clockwise direction. Make sure it is shut tight. Then turn over the blowtorch, bottom up. Unscrew the wing plug, being careful not to misplace the washer or gasket on it. Fill the tank no more than three-quarters full with plain gasoline. The other quarter space is needed later for air pressure. Replace the plug and washer, making sure they are tightly in place. Place the torch in an upright position. Pump enough air into the gasoline tank so that the pressure will be sufficient to cause the gasoline to flow when the jet valve is opened.

The torch cannot work properly until the burner has been heated sufficiently. This is done, as will be explained later in detail, by filling the preheating trough with gasoline and igniting it.

Priming cup. Never open the jet valve suddenly. If it is not opened very slowly, a jet of gasoline may shoot into the room. This will evaporate and release gasoline fumes which later, when a match is struck, may ignite, causing a fire.

Opening the jet valve will permit the gasoline fumes to enter the burner tube. However, if the palm of the hand is placed at the end of the burner while the jet valve is being slowly opened, the gasoline cannot escape through the burner tube. Instead, it enters the preheating cup or trough. When this is almost full, turn off the jet valve tightly.

Igniting. You should then ignite the gasoline, but before doing so, take certain precautions. Be sure that the hand that held the burner end is absolutely dry and free of gasoline. Do not use it to hold the match. Check to see that the blowtorch itself is dry and free of gasoline in every spot except the preheating cup. If these precautions are not observed, the entire torch may be engulfed in flames later or your hand may be covered with flames. Make sure that there is nothing combustible near the torch and that it is at a considerable distance from the storage of gasoline. Examine all adjustments to see that they are properly made. Do not operate the torch in a draft.

Light a match and ignite the gasoline that is in the preheating cup. Be sure that this is done at arm's length from the torch. Avoid having your face above the torch or your body bent over it while doing this. Make certain that you have safely put the match out after lighting the torch.

When the gasoline in the preheating cup has been almost completely used up, very slowly turn open the jet valve. The burner should start to operate immediately with a yellowish orange flame, blowing with considerable force. If it does not blow strongly enough, a few strokes on the air pump will help. The flame will stay yellowish orange until the gasoline in the preheating cup is entirely used up. If, after this, it still remains colored, it means that the burner has not been preheated sufficiently. In that case do *not* add more gasoline to the preheating cup. This would be extremely dangerous to do while the torch is hot and there is a flame in the burner. Instead, bring the burner end close to but not touching a steel plate. This will cause the heat being generated to concentrate around the burner, thus giving it the additional heat needed for thorough preheating. Soon the flame will turn to an intense blue, which is the correct color for operating the torch.

The size of the flame is controlled by the jet valve. The force of blowing is controlled by the amount of air pumped into the gasoline tank. As the air pressure decreases, the force of the flame decreases.

To turn off the flame, shut the jet valve. When the flame is out, turn on the jet valve slightly. This will liberate gasoline to wash off the carbon and so clean the burner. Further, as soon as the flame is put out, the torch begins to cool. Cooling metals usually contract. Thus a valve that was shut tightly and then contracted through cooling would become so jammed that later it could not be operated.

When the torch is to be put away for a long time, the gasoline should be emptied from the tank and the jet valve left open slightly.

When heating a soldering copper, it should be rested on the hooks attached to the torch for this purpose. However, the point of the bit should never be directly in the flame.

5. SOLDERING OPERATIONS

The following is a summary of instructions for soldering:

(1) Start heating the soldering copper.

(2) Clean the surfaces to be soldered. Cover with flux.

(3) Make sure that these surfaces fit and contact each other as perfectly as possible. Do not rely on the solder to fill up cavities or correct imperfections of shape.

(4) Tin the soldering copper, if necessary. If not, place it in contact with the metal. Make sure that a face, not the point of

the copper, rests on the metal, because the whole purpose is to transfer the heat directly and as quickly as possible from the copper to the metal.

(5) Hold the solder at the extreme end of the copper tip. As the solder melts move the copper and the solder along.

(6) Avoid a heavy layer of solder. It has been found that a thin layer of solder is much stronger than a heavy blob of solder. Excess solder may be wiped off with a rag, or moved along with the soldering copper to an unsoldered portion of the job.

(7) If the area to be heated is large or the metal is very heavy, preheat with the torch. Avoid too much heat. Keep the flame away from the spot where the solder is to be applied. This will prevent oxidizing that spot.

(8) If the joint to be soldered is very long and there are no rivets or locks to hold the metals in place, first place a drop of solder every few inches on the length of the seam to hold the metals in place. This is called *spotting.* (See Fig. 5–38.) Later, as the soldering progresses, these drops are melted and flowed into the joining.

(9) If the surfaces to be soldered are very wide, first tin each surface. Then, holding the metals in close contact with each other, place the soldering copper on the metal. This will fuse the two tinned surfaces together. It is called *sweating.*

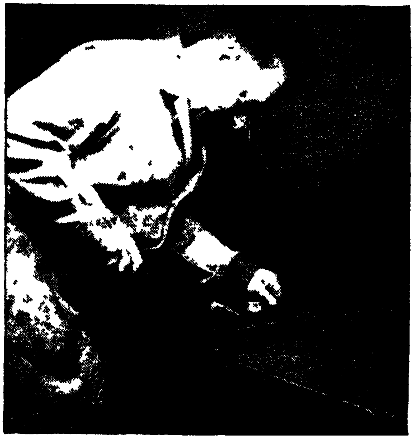


FIG. 5–38. Running seam, or spotting, with solder.

(10) If solder must be applied on the undersurface of a seam, tin only one face of the soldering copper. In that way it will be the only one that can hold the liquid melted solder. Solder according to the instructions already given. If all the faces of the

copper were tinned, the melted solder, not being able to run up hill, would run off the top face, away from the work, and clump on the lowest face.

(11) Do not touch or disturb a soldered joint until it has cooled and, therefore, fully set. Allow it to cool naturally. Do not force it by attempting to cool it with water, for this would result only in an unevenly contracted joint and in making the solder itself brittle.

6. SOLDERING SPLICES

The soldering of splices in wires is a common operation in almost every electrical wiring project. It is explained in detail on pages 326-341.

Emergency soldering. If no other heat source is available, a series of matches can be used for soldering wire splices and small joints. It is necessary, however, to keep the smoke from making a deposit on the surface before it is hot enough to melt the solder. This can be done by coating the joint or splice with a heavy paste flux with the solder embedded in it. The solder will flow as soon as enough heat has been applied.

I. PRESERVING FINISHES

We learned that to increase the life of wood, we must protect it from such external things as molds, bacteria, and moisture. Similarly, metal must be protected from its enemies, which are mainly moisture, oxygen, and corrosive fumes. As with wood, the life of metals can be extended by protecting them with the proper coatings and finishes. Often the beauty of metal objects can be increased, too, by using an appropriately colored finish. This, however, is of secondary importance.

Corrosion. Corrosion is the eating away of a metal. For example, an acid combines with a metal and the metal is eaten away. Rusting of iron, called *oxidation*, is another example. The oxygen in the air joins with iron to form the familiar brownish rust.

When oxygen joins with copper, as in a brass alloy, or when even a slight trace of sulfur in the air joins with silver to blacken it, these metals are said to *tarnish*. Corrosion may be fast or slow, complete or partial. Pure iron readily rusts, and rusting may be so complete that the object completely disappears. Brass, lead, copper, and aluminum all oxidize very slowly.

Corrosion may be on the surface or inside metals. In an alloy, internal corrosion may be the result of both chemical and electrical reactions between the metals that compose it. Internal corrosion is especially dangerous because often there is no sign on the surface that it is taking place, even though it may start from a scratch or nick in the protective coating of the metal.

Corrosion may also take place if two different metals are placed so that they touch each other, especially if the air is salty and damp. The same scientific principle accounts for this and for what has already been said about the internal electrochemical action in alloys. It is the same action that takes place inside an electric battery. To prevent corrosion caused by the electrical action that sets up between two unlike metals, the surfaces in contact with each other must be insulated or plated or both. For example, steel that touches an aluminum or copper alloy should be plated with cadmium and then insulated with two finish coats.

Plating. The purpose in plating is to cover an easily corroded metal with a layer of a metal that resists corrosion, such as cadmium, nickel, and copper. For example, steel bolts, nuts, small welded parts, and the like should be cadmium plated.

Electroplating is a highly technical process. Briefly explained, the apparatus used consists of a container that cannot conduct a current, as vulcanized rubber, glass, or porcelain. In it is poured a solution of the salt of the plating metal, as copper sulfate for copper. A bar of the plating metal and the object to be plated, thoroughly cleaned, are correctly attached to wires from a source of direct current and placed in the solution.

Cadmium is a soft, ductile, corrosion-resisting metal, extensively used as a plating metal in the airplane industry. However, it is not tough or hard, and therefore can easily be scratched off the object it coats. On the other hand, even a very thin layer of cadmium plating is highly corrosive-resistant. Chromium plating is used where high luster, hardness, and resistance to scratching, corrosion, and oxidation are required.

Metalizing. Where it is impossible or unpractical to electroplate, yet a coat of metal is desirable, the metalizing process is used. This consists of spraying molten metal on the part to be finished. The object is first sand-blasted to roughen its surface and remove all oxide and scale. Then a small blowtorch of a special type is used. The coating metal, in the form of a wire, is fed into the torch and melts instantly. An air blast strikes the molten metal, turns it into a spray, and drives it into every crack and curve of the object to be metalized.

Anodic treatment. To protect them from corrosion and to provide them with a coating that will hold other finishes, aluminum and aluminum-alloy parts are given the anodic treatment. The object to be treated is placed in a solution of chromic or sulfuric acid and an electric current is passed from the part through the solution to the metal container. This places a film of aluminum oxide on the entire surface of the object. The film is corrosion-resistant, but is very thin and easily scratched. This operation may appear to be a plating process, but it is not, for no pure metal is deposited on the surface of the work.

Primers. Primers on metals serve as a binding coat similar to the aluminum oxide deposited in the anodic treatment. Drying a dull flat, primers provide a much better surface for holding other coats of paints than if they were put directly on the smooth, shiny surface of the cleaned metal.

Zinc chromate, in a synthetic gum or plastic base, is used as a primer in aircraft finishing for aluminum alloys and other metals. Since it dries rapidly, in from 15 to 20 minutes, no time is wasted in applying subsequent finishes.

Primers are applied by spraying or dipping. No other method can give the same resultant evenness and smoothness. Touching up is usually done by brushing.

Lacquer. Lacquer consists of cellulose nitrate liquefied in a solvent such as amyl acetate. Other chemicals are generally added to prevent cracking when dry. Lacquer is fast drying and colorless. Colored pigment can be added to provide an artistic finish.

In the aircraft industry, lacquer is often called *dope.* Dope is applied to fabrics, as wing covers on planes; it shrinks them and produces a smooth, tight surface. The dope is first applied by flowing it on with a brush to provide a good soaking. Subsequent coats are sprayed on.

When prepared with just enough solvent to make it a thick mass, dope makes a fine glue or cement for all materials except rubber. A cheap mixture can easily be made at home or in school by preparing a 2–1 mixture of acetone and alcohol. Into it are placed small pieces of celluloid, such as handles of old tooth brushes, damaged triangles from the drafting room, and the like.

Metals, such as brass and aluminum, that have been highly polished with abrasives, can be made to keep this high luster for a considerable length of time by completely coating them with a thin layer of lacquer.

Once the metal has been cleaned and dusted, do not touch it with the fingers. Since the slight dampness and salt in the skin are enough to spoil good results, it is best to wear gloves, but be sure they are free of lint. Work rapidly; do not allow the metal to be covered with oxide. The room should be draftless so that the work is not affected by dust. It is best to spray on the lacquer, which provides an even, smooth coat. If it cannot be sprayed, lacquering should be done with a camel's-hair brush. Since lacquer dries rapidly avoid brushing over, which produces a rippled or uneven surface.

Paints and varnishes. These were already discussed in detail in the unit on Woodworking. They also serve as excellent coatings for metals.

All iron and steel objects should have a protective coating.

Generally a coat of red-lead paint is used as a priming coat, and then a finish coat of paint is applied. Red-lead paint is a mixture of red oxide of lead in linseed oil, with a thinner like turpentine and a drier.

Before the red lead is applied, the metal must be free of grease and rust. Emery cloth can be used to remove the rust. If all rust is not removed, the metal may continue to oxidize even under a good coat of red lead.

Galvanized iron or steel should be weathered for several months to get rid of the greasy surface resulting from the manufacturing process and to provide a rough surface to hold the red lead. The same effect can be obtained almost immediately by first painting the galvanized surface with a solution of vinegar and permitting it to dry thoroughly before painting.

Moving parts, such as bearings, pulleys, and the surfaces of machines, even though made of steel, should not be painted. They should be greased or plated; sometimes they are covered with lacquer or shellac

Aluminum paint, consisting of two pounds of flaked aluminum metal to each gallon of varnish, is also an excellent priming coat for metals as well as for wood. It has the additional advantage of being an attractive finish coat. Since aluminum paint tends to settle quickly, it should be stirred often as the painting job proceeds.

When old metal work needs repainting, all loose paint should be chipped off. Only places where the metal is exposed should be touched up with red lead or aluminum paint. If the old paint work is in very poor condition, it should be completely removed with a paint remover. After the paint remover has been applied, it should be thoroughly washed off so that not the slightest trace is left. If not, it will prevent the new coat of paint from sticking. An alkaline paint remover is made by dissolving three pounds of washing soda or trisodium phosphate in a gallon of water. It is an excellent and cheap remover. If the water is applied boiling hot, it is even better.

Naturally a liquid remover can best be used on horizontal surfaces. For vertical surfaces a paste remover is better. Dissolve a can of lye in two quarts of water. Add enough hydrated lime to make the mixture as thick as putty or very heavy paint. Apply with a putty knife and scrape off after half an hour. Repeat the process until all the paint is removed. The paste remover can be used time and again, and if it hardens you can soften it with water. At all times be careful that the paste does not touch the skin, for it can cause a serious burn. Use rubber gloves while doing the job.

Other removers are made of combinations of acetone, gasoline, benzol, wood alcohol, and the like, with the addition of wax to prevent too rapid evaporation. They are an extremely dangerous fire hazard, and therefore proper care should always be exercised.

J. METALWORKING SKILLS AND KNOWLEDGE

In your study of metalworking you have been learning how to handle and care for metal tools, and materials. You have learned how to lay out metal, cut it, join it, and finish it. The following table lists some of the skills and new knowledge you have been gaining, and also some jobs, projects, and exercises which you should be able to carry out. The numbers following each entry show the pages in this book on which that topic has been discussed.

Things You Should Be Able To Do	Things You Should Know	Suggested Jobs, Projects, and Exercises
Sharpen a knife, 98–99.	The parts and cutting blade angles of a knife, 4–5. How to prevent loss of the temper of the blade in grinding operations, 51–52.	Recondition a knife.

THINGS YOU SHOULD BE ABLE TO DO	THINGS YOU SHOULD KNOW	SUGGESTED JOBS, PROJECTS, AND EXERCISES
Grind a new screwdriver point, 102–103.	How to test a screwdriver with a screw slot, 101–102.	Repair a broken screwdriver blade.
Use sets of screwdrivers, 100–102, 104.	The proper sizes of screwdrivers, 100–102. How to prevent injury, 103–105.	Drive, tighten, and adjust screws.
Make linear measurements with a steel scale, 5, 111–117.	Graduations in 8ths, 16ths, 32nds, and 64ths, 112–113.	Check sizes of materials. Check layout measurements.
Read a micrometer caliper, 121–127.	The mechanics of a micrometer, 121–127. Revolution line graduations, 124. Thimble graduations, 125.	Check sizes of wire and sheet metals.
Read a vernier scale, 127–130.	The principle of a vernier and its applications, 127–130.	Construct vernier scales on strips of paper.
	Gages of sheet metals, 120.	Make a sheet-metal safety guard for power grinder.
Cut metals with hacksaw and power saw, 256–258.	Grades and sizes of hacksaw teeth, 254 and 256. The direction of the teeth with relation to the cutting stroke, 255.	Remove and replace damaged machine parts.
Cut sheet metals in a vise with a cold chisel, 45.	The cutting angle of a tool edge, 43–44. How to direct shearing cut, 43–44 and 293.	Make sheet-metal patches.

THINGS YOU SHOULD BE ABLE TO DO	THINGS YOU SHOULD KNOW	SUGGESTED JOBS, PROJECTS, AND EXERCISES
Drill small holes with a hand or breast drill or a power drill press, 258–269 and 276–277.	How to correct punch marks, 261. How to select proper drill sizes, 263. How to determine drill speeds and feed pressures, 263–265.	Resharpen broken drill points.
Sharpen drills for hard or soft metals, 265–266.	Proper angles for drill bits, 265-266.	Drill and wire a safety bolt.
File hard and soft flat metal surfaces, 249–252.	Kinds and uses of files, 244–247, 249–254. The care of files, 247–249 and 253–254.	
File curves, 252.	Shapes and sizes of files, 246-247. How to use chalk to prevent clogged file teeth while filing soft metals, 248.	Make metal machine parts. Make bracket supports.
Draw-file a surface, 252.	How to finish filed surfaces, 252.	
Cut screw threads with taps and dies (screw plate), 269–280.	The uses of bottoming, plug, and taper taps, 274–276. How to start taps and dies, 277-280. How to use drill and tap-size charts, 289.	Make jigs and fixtures.
Remove broken machine screws and broken studs, 295–296.	How to reslot screw heads, 295. How to use screw-plug extractors, 295-296. How to drill out centers and split screws, 296.	Remove and replace broken studs in metals.
Remove rust from metal surfaces, 300.	How to use steel wool and emery cloth for hard metals, 296 and 297. Preventing injury by wearing gloves, 297.	

THINGS YOU SHOULD BE ABLE TO DO	THINGS YOU SHOULD KNOW	SUGGESTED JOBS, PROJECTS, AND EXERCISES
Clean and polish tarnished soft metals, 296–297.	How to use steel wool and metal polish, 297. When and how to use crocus cloth, 296.	Restore metal surfaces on equipment.
Prepare metals for soldering, 300.	How to clean and remove surface oxidation, 300.	
Use of the proper fluxes, 300-302.	The use of corrosive flux for zinc, iron, etc., 300-301. The use of noncorrosive flux for brass, copper, etc., 301-302	
Reshape the point of a soldering iron (copper) with a file, 304.	The length of taper equals 1¼ times the thickness of the body, 301.	
Clean a pitted soldering-iron point, 304.	How to file the point and wipe it with steel wool or a wet clean cloth while the copper is at the correct heat, 304.	
Heat a soldering iron externally, 302, 304, and 306-310.	How to use a blowtorch, 306–308. How to guard against both gas and gasoline fumes and fire, 307–308.	
Tin a soldering iron, 305.	How to use a sal ammoniac block, 305. How to wipe off excess solder, 305.	

THINGS YOU SHOULD BE ABLE TO DO	THINGS YOU SHOULD KNOW	SUGGESTED JOBS, PROJECTS, AND EXERCISES
Tin metal surfaces and sweat them together, 308–310.	How to get a thin, even coat of tin on surfaces, 308–310.	Repair fire extinguishers.
Solder joints and splices, 310.	How to clean, apply flux, and solder right joints with a minimum of solder, 326–327.	Repair radiator leaks. Solder leaks in water cans.
Fasten metals with rivets, 289–293.	The size, shape, and uses of rivets — copper, iron, aluminum, hollow, split, solid, etc., 294–295. How to use a rivet set, 293.	Tighten loose rivets.
Remove rivets by cutting heads, 293–295.	How to use a cape chisel to slot a rivet head, 294. How to shear off rivet heads with a cold chisel, 293 295.	Strengthen joints by replacing rivets.
Preserve metal surfaces, 310 and 314.	How to clean metals, 300 and 314. How to prevent rust on files, 248. How to lacquer bright work, 313. How to paint rough surfaces, 313–315. .	Maintain and clean machinery and equipment.

SUMMARY

1. Some common metals are iron, aluminum, nickel, copper, lead, tin, zinc, and magnesium. Some common alloys are bronze, brass, stainless steel, and babbitt metal.

2. Manufacturers supply metals to industry in a variety of forms, such as sheet, plate, bar, wire, and band. Men can treat metals or alloys by molding them, stamping or pressing them into shape, working them on lathes and milling machines, and by heating and beating them.

3. The layout tools most often used for metalwork are the steel scale, the divider, and the scriber. Others are the square and the center punch.

4. Various types of files are used for smoothing and shaping metal. Flat filing is a means of giving a fine smooth finish to the surface of metals. Draw filing makes a smooth and level surface. In shape filing, round surfaces should be filed with a rocking motion.

5. Hacksaws are used for cutting metal, the blade used being determined by the kind of stock. The power hacksaw does all the work of the hand hacksaw but does it more efficiently and quickly

6. Holes are made in metal by punching or drilling. Drills may be run by hand or by power.

7. The center punch (1) locates permanently the center of the hole that is to be drilled, and (2) makes a slight depression to provide a start for the drill point.

8. Nuts, bolts, screws, and studs are used for holding machine parts together or in place. All are threaded. Threads may be cut by machine or by hand. Internal threading is made with a tap and tap wrench. External threading is made with a die and stock.

9. A nut is a small piece of metal drilled with a hole threaded to match the threads of a bolt, screw, or stud.

10. Bolts with nuts are used for holding together two or more separate pieces. Screws are generally used in tapped holes.

11. Washers are discs of metal used with screws, studs, bolts, and nuts to protect the surface of the metal, to provide a larger clamping area, or to keep nuts and bolts from loosening.

12. By counterboring or countersinking you may enlarge a hole for part of its depth so that it will receive the head of the screw and the head will be flush with the surface of the metal when the screw is tightened.

13. Rivets are used when two materials, especially metals, are to be joined permanently.

14. To drive a rivet: (1) locate and punch or drill the rivet holes, (2) choose the proper type and size of rivet, (3) insert the rivet in the hole so that the head is under the work resting on a solid surface, (4) hold the pieces of metal together firmly, (5) with a peen hammer strike straight down on the rivet with four or five heavy blows, (6) form a head by striking the outer edges of the upset rivet end with glancing blows, gradually circling the rivet.

15. Emery cloth and crocus cloth are used for preparing metal surfaces, emery cloth for hard metals such as iron and steel, and crocus cloth for producing a high polish on soft metals such as aluminum, copper, and brass. Wire brushes are used for such things as cleaning surfaces, brushing off rust scales, and smoothing up rough castings. Steel wool is used in polishing metal, removing paint, and general rough cleaning.

16. Soldering is used to join two or more separate pieces of metal. It consists of applying a melted alloy to the metals so that when the work cools they are joined together rigidly.

17. A flux is used to prevent the clean metal surface from uniting with the oxygen of the air before it can be soldered. Fluxes may be corrosive or noncorrosive.

18. Soldering coppers furnish the heat needed to (1) melt the solder and flux, and (2) raise the temperature of the metal to that of the melting point of the solder.

19. Blowtorches are used in cases where the soldering equipment must be brought to the job. Some blowtorches use gasoline for fuel. Others use alcohol. For summary of soldering operations, see pages 308–311.

How many of the following terms can you define or explain?

Muffle
Puddling
Ashton process
Lead burning
Threads
Welding
Stretch out
Pinning
Tap
Blind hole
Dies
Tinning
Cotter pin
Riv-Nut
Drill
Bore
Drawing
Sweating

SELF-TESTING EXERCISES

ANSWER THESE QUESTIONS

On a separate sheet of paper numbered from 1 to 7 write the letters for the phrases that answer the following questions correctly.

1. Which kind of iron is used in making most of an automobile engine? (*a*) Cast iron; (*b*) malleable iron; (*c*) annealed gray iron; (*d*) wrought iron.
2. Which kind of file would you use to remove metal quickly if the resulting rough surface was not of particular concern? (*a*) The mill file; (*b*) the round file; (*c*) the equaling file; (*d*) the machinists' file; (*e*) the slotting file.
3. Which kind of tap would you use to start internal threading? (*a*) Bottoming tap; (*b*) plug tap; (*c*) taper tap.
4. Which type of nut would you use if the tension was not great and you could use the fingers for tightening? (*a*) The coupling nut; (*b*) the wing nut; (*c*) the check nut; (*d*) the castle nut; (*e*) the slotted engine nut.
5. Which kind of screw would you use for holding a wheel, knob, or collar rigidly in place on a shaft? (*a*) The lag screw; (*b*) the drive screw; (*c*) the fillister head screw; (*d*) the set screw.
6. Which kind of rivet would you use where streamlining is needed, as in an airplane? (*a*) A round-head rivet; (*b*) a flathead rivet; (*c*) a countersunk rivet; (*d*) a tubular shank rivet; (*e*) a brazier-head rivet.
7. Which abrasive would you use to give a high polish to a soft metal such as aluminum? (*a*) Emery cloth; (*b*) steel wool; (*c*) a wire brush; (*d*) crocus cloth; (*e*) carborundum.

COMPLETE THESE STATEMENTS

On a separate sheet of paper numbered from 1 to 20 write the words needed to fill correctly the blank spaces in the following sentences.

Bronze is an alloy of (1) and . (2) . . . The form of metal most often used by industry is . . (3) . The presence of thin sheets of . . (4) . . makes cast-iron castings very rigid. If holes are to be drilled a . (5) . . is used to scribe lines corresponding to the center lines in the drawing. Machinists and toolmakers often . (6) . . steel and iron surfaces in preparation for scribing. The . (7) . . the file is pushed the less chance there is of rounding the corners of the work while trying to square it. Never use a file without a . (8)... In a raker set hacksaw every third tooth remains ..(9)... A . (10).. blade is used for sawing hollow shapes and metals of light cross section. Start hacksaw cuts by having the blade almost ..(11).. to the work. . (12). is a good lubricant for drilling aluminum. The harder the material the .(13) . should be the speed of drilling. If a hole is to be cut through, be careful that the drill does not go through ..(14) .. All taps have (15) shanks to permit the use of a wrench for turning them to cut the thread. When metals themselves are melted and joined together the process is called ..(16) . Soft solder is commonly a half-and-half mixture of (17). and (18)... Hard solder is composed mainly of ..(19).. and other metals such as copper and .(20) ..

Are These True or False?

On a separate sheet of paper numbered from 1 to 10 write a T *or an* F *to show whether each statement is true or false.*

1. Malleable castings may be welded without ill effects.
2. Wrought iron cannot be used for casting.
3. Coarseness of a file varies according to its length.
4. When draw filing, pressure may be maintained on the return stroke.
5. Soft solder may be used for filling cracks or pits to give a smooth-looking surface.
6. In repointing the tip of a soldering copper, the length of the taper should equal $1\frac{1}{4}$ times the thickness of the soldering copper body.
7. The correct color of flame for the operation of a gasoline blowtorch is blue.
8. The size of the flame is controlled by the amount of air pumped into the gasoline tank.
9. The force of blowing is controlled by the jet valve.
10. A thin layer of solder is much stronger than a heavy blob of solder.

QUESTIONS

1. What part of the process of making cast iron produces "sharp" castings?
2. Why are gun parts made of malleable iron castings?
3. How could you soften copper that had become hardened from being hammered or rolled, or brass that had been hardened by hammering?
4. What six factors determine the proper feed pressure for a power drill?
5. What is the most common cause of drill failures?
6. Why must you not make the slightest attempt to bend a tap?

7. What is the proper angle between the stock and the rod when you you are cutting external threads?

8. In cutting pipe threads why are the last few threads tapered?

9. What are explosive rivets used for?

10. What precautions should you take when making zinc chloride for use as a corrosive flux?

11. Why must you be careful to use only plain, unleaded gasoline in a blowtorch?

12. What precautions should you take in igniting a gasoline blowtorch?

13. What should you do if you find the preheating cup of the gasoline blowtorch has not been sufficiently heated? What must you not do? Why?

14. For what two reasons should you turn the jet valve slightly after you have turned off the flame?

15. How would you proceed if the joint to be soldered were very long and there were no rivets or locks to hold it in place?

VI

Wiring and Wire Splicing

The age we are living in has been called the Machine Age, the Air Age, the Steel Age, the Plastics Age, and so on. It is as logical to call it the Age of Electricity. Without electricity, the automobile and airplane would be helpless; the radio, telephone, and telegraph would be silent; the X-ray machine, the bloodless knife, and other medical apparatus would be lacking; factories would have to be located close to coal mines, oil wells, or water power rather than scattered strategically about the country; recreation would be greatly limited — without electricity our lives would be much different! Too, communication and transportation are the nerve and heart of most Army and Navy actions, and electricity is important in making them possible.

One electrical apparatus may look entirely different from another, but all electrical machines have one requirement in common: they must have conductors, that is, wires for the passage of the electric current. Conductors are also needed to bring electrical power to the home and the factory; to carry electrical impulses to telephone and telegraph sets; to operate radio transmitters and receivers, moving-picture projectors, and the like.

How are electrical conductors joined? How are branches led off? How are wires attached to electrical apparatus? This is knowledge everyone working with electrical equipment must have, from the electrician's helper to the electrical engineer.

A. BUS WIRING

It is sometimes necessary to make the internal conductors and connections in electrical equipment strong and rigid, as, for example, on electrical control boards and in radio sending and receiving sets. This is especially important in short-wave sets where poor adjustment of one or more wires may change the wave length to which it is tuned. Such maladjustment can easily take place in sets subject to exceptional jarring, such as those used in planes, automobiles, and tanks.

To obtain rigid and strong conductors, *bus wire* (also called *bus bar*) is used. Bus wire may be round or square; the square form is used more often. It is No. 14 gage, or heavier, copper wire. Often bus bar is coated with a thin layer of tin (solder) or enamel. This prevents corrosion (rusting, oxidation, or the eating away by chemicals) and makes soldering easier.

In addition to having strength and rigidity, a set built with bus bar is neat and workmanlike in appearance. However, it is much more difficult to build or fix a set made with bus bar than one made with the usual flexible wiring. Usually changes in direction of bus wire are made with a right-angle bend. All wires running in the same direction are parallel to each other and are generally either in a vertical or horizontal position. Horizontal wires are parallel with or perpendicular to the panel.

Bus wires have no insulation; therefore they must be properly spaced from each other to avoid short circuits. Sometimes, though, because of lack of space they must be close together. In such instances a tube of insulating material called "spaghetti" is slipped over the bus wire before it is soldered into place.

Of the several ways of joining bus wires, we shall here consider only two: butt joint and loop joint.

1. BUTT JOINT

In the woodworking shop, a butt joint is made by simply attaching one piece of wood to another. Similarly in bus wiring, a butt joint consists of fastening two wires together, face to face, as shown in Figure 6–1. The steps in making this joint are as follows:

(1) Bend one wire $\frac{1}{4}''$ to $\frac{1}{2}''$ from the end to form a right angle. Do not make too sharp a bend, for that nicks the wire and makes

it possible for it to break easily. The corner of the bend should be rounded as shown in Figure 6–1*A*.

(2) Thoroughly clean the bent portion of this wire and the spot on the other wire where the joint is to be made.

(3) Place the bent portion of the one wire properly aligned on the second wire at the place where the joint is to be made, as shown in Figure 6–1*B*.

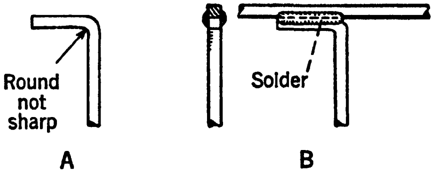


FIG. 6–1. A butt joint.

(4) Flow a small bit of solder between the two wires, adding a bit more solder to build up the joint.

The butt joint is generally used only with square bus wire. The reason for this is that the sides of two squares can touch each other over a greater area when set together than the sides of two circles (rounded wire) similarly placed together, which touch each other only on a line.

2. LOOP JOINT

This type is generally used with round bus wire as shown in Figure 6–2. The steps in making it are as follows:

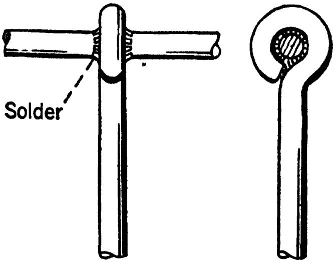


FIG. 6–2. A loop joint.

(1) Make an open loop on the end of one wire.

(2) Place the loop over and around the other wire at the point where the joint is to be made. With the pliers, close the loop and clamp it into place.

(3) Solder the joint, taking care to see that solder flows into the loop.

If enameled wire is used in butt or loop joints, the enamel must be removed from both wires at the place of joining before soldering. To do this, scribe a fine line through the enamel and around the wire at the proper place. Then scrape off the enamel from the scribed line to the end of the wire. Naturally, if the place of joining is at some spot along the wire, not at the end, then two lines must be scribed around the wire and the enamel carefully scraped off between the two.

The butt joint is weaker than the loop joint. The two wires of a butt joint are held together only by the solder. In the loop joint the two wires are not only held together by solder but one wire is clamped around the other.

B. TERMINALS

In electrical work a *terminal* is generally considered to be the connection made between an electrical apparatus and the external wiring circuit. Thus wires are attached to fuse blocks, telephone sets, switches, plugs, and the like in many different ways. Some of these methods are forming a loop (as explained later), holding the loop in place with a screw, and using lugs and terminal punchings.

1. LUGS

Cup lugs. Cables and wires that end at power boards and other apparatus are often sweated into terminal cup lugs for attachment. *Cup lugs* are electrical fittings with cup-shaped hollow ends for inserting wires. *Sweating* consists of holding together two or more parts that were previously coated with solder and heating the assembly until the solder coats melt and join all parts of the assembly into one piece. The steps in using cup lugs as terminals are as follows:

(1) Remove the insulation on the wire for a distance a little shorter than the depth of the cup on the lug. Clean the wire and tin it.

(2) Clean the inside of the cup and tin it. Melt into the cup enough solder to fill, allowing for the volume of the wire to be

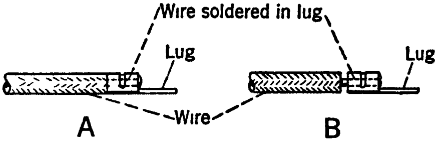


FIG. 6–3. The right way (*A*) and wrong way (*B*) to make a cup lug.

attached. Use a blow torch for larger cups and the soldering iron for smaller cups.

(3) While the solder is still soft, insert the tinned end of the wire into the cup so that the insulation of the wire just touches the rim of the lug. (See Fig. 6–3.) Allow the joint to cool before disturbing it.

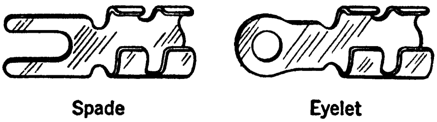


FIG. 6–4. Two types of clamp lugs.

Clamp lugs. These are similar to cup lugs except that in place of cups there are clamps for fastening the lug to the wire. Figure 6–4 illustrates two types of clamp lugs, spade and eyelet forms. The clamps must be turned tightly around the insulated part of the conductor. Then the wire is soldered to the lug to provide a good electrical contact.

If the lug is the kind that has a small hole, the strands of the wire are pulled through the hole, separated into two halves, bent back and soldered. They should not be pretinned, because then they could not be easily separated, inserted, and bent as described above In this type of clamp lug, the strain on the soldered connection is relieved.

If there is the slightest danger of short-circuiting, the exposed clamps of the lug should be insulated. This can be done by wrapping a strip of rubber tape around it or slipping a small piece of tight-fitting tubing over the exposed part.

Clamp lugs are stronger than cup lugs because the conductor has not only a soldered attachment but a mechanical attachment as well. Further, cup lugs can readily snap off the wire. The continuous metal backing of clamp lugs prevents them from bending easily and breaking off.

Soldering precautions. Keep the metals as close together as possible. Do not use too much solder, especially between the metals. Avoid lumpy joints that offer too much electrical resistance. Half-and-half solder, the type usually employed, has only one-seventh the conductivity of copper; thus surplus solder will increase the resistance to a current and cause unnecessary heating at the joint.

For every soldering job a *flux* must first be used. The flux cleans the metals, prevents the oxygen of the air from joining them, and helps them to unite. If this takes place, an oxide coats the surface of the metal and prevents the solder from joining it. Therefore, the metal should first be thoroughly cleaned to remove all dirt, grease, and oxide, and then quickly covered with the flux. In electrical work *corrosive* fluxes such as zinc chloride, hydrochloric acid, sal-ammoniac, and the like should never be used, for if they are not completely removed after soldering, they will in time eat through the wire. Only *noncorrosive* fluxes, such as rosin, should be used for electrical work.

Sometimes solder comes in the form of a hollow wire with the rosin flux in its center. Avoid making a rosin joint, which is a poor conductor of electricity and offers high resistance. Rosin joints occur when the solder is sweated to the wire, but the rosin flux lies between the wire and the lug. This can be caused by a number of things: the lugs and wire may not have been cleaned and properly tinned; the soldering iron may not have been hot enough; the rosin, which has a lower melting point than solder, may have been melted and the solder only partially melted; the wire and lug may not have been heated enough before applying the solder. (See pages 302–304.)

Of the two methods of soldering splices, sweating is preferred. The other method consists of holding a hot soldering iron on top of the splice and running the solder into the joint.

Sometimes terminals must be soldered near parts having sealing compounds, as in transformers. Such sealing compounds have a much lower melting point than solder. Use just enough heat to melt the solder, but use enough to avoid rosin joints. Too much heat may melt the sealing compound and spread it over the job. (See Fig. 6–5.) The insulation should never be cut back too far beyond the lug. This offers too great a possibility of short-circuiting. Figure 6–5 shows some other examples of improper soldering.

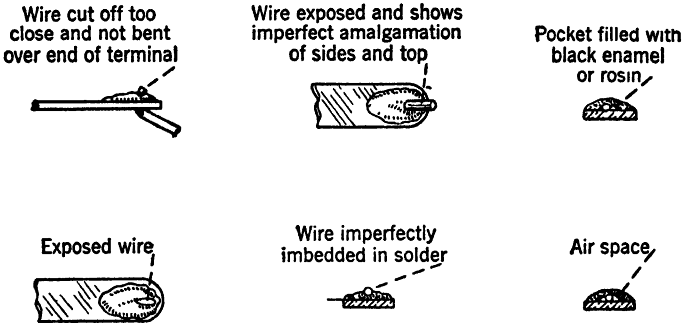

Wire cut off too close and not bent over end of terminal
Wire exposed and shows imperfect amalgamation of sides and top
Pocket filled with black enamel or rosin
Exposed wire
Wire imperfectly imbedded in solder
Air space

FIG. 6–5. Improper soldering.

2. TERMINAL PUNCHINGS

We have already learned that terminals are the connections of wires where they are attached to electrical apparatus. We further learned that there are several kinds. When they are small or stamped from a flat sheet of metal, they are called *terminal punchings* or *punched terminals.* Sometimes they may be specially shaped to provide clearance and accessibility. (See Fig. 6–6.)

When several punchings are employed, they must be held in place by a mounting. Some are mounted individually, and some in groups of two or three by means of screws or merely inserted into the wood frame of an instrument. Most often they are mounted in terminal blocks such as the one shown in Figure 6–7. This diagram also shows the manner of attaching the wire to the terminal punching and placing the punchings in the block.

In the block shown it should be noted that the wires are led in on the left side and under their respective punchings. Also, the insulation of the wire comes up to, but not into, the notch of the terminal. The cleaned wire goes into the notch of the terminal. When soldering wire to a terminal the solder must be placed just on the spot where it belongs. If it runs or drops off, short circuits may result.

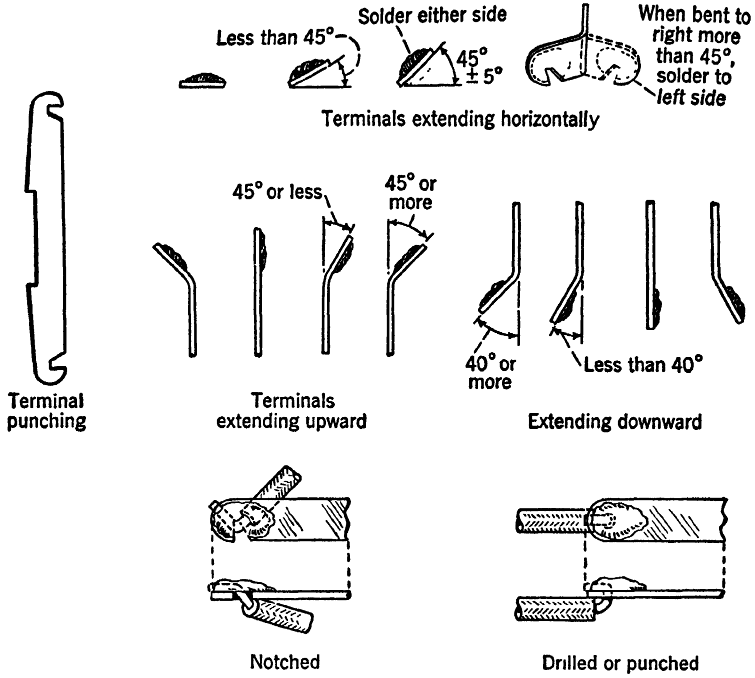


FIG. 6–6. Some types and positions of terminals.

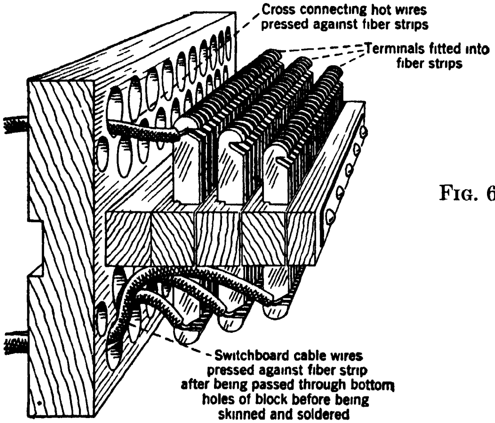

Cross connecting hot wires pressed against fiber strips
Terminals fitted into fiber strips
Switchboard cable wires pressed against fiber strip after being passed through bottom holes of block before being skinned and soldered

FIG. 6–7. A terminal block and punchings.

Sweating the small terminals of radio and telephone apparatus is not advisable because the method is too slow and too much heat is required. They can be soldered in the following manner. Lay the end of a strip of rosin-cored solder lengthwise on the terminal so that it extends over the spot that is to be soldered. Place the tip of a properly heated soldering iron on the solder. As soon as it melts, draw the rest of the solder away from the iron tip. When the solder is liquid and is sticking to the terminal and wire, remove the iron by moving it toward the end of the terminal. Permit the joint to cool before handling the wire or terminal. Remove excess solder by remelting it and brushing it off with a thin stick or toothpick.

While working on terminal blocks, relays, and the like, protect any wiring or equipment that may be below by covering it with a piece of canvas or cheesecloth When the work is completed the cloth should be carefully removed, carrying away all excess solder and wire skinnings.

C. LOOP BENDING

At times an electrical connection must be made by bending a wire around a screw which, when tightened, makes a good contact between the wire and the apparatus. However, for the electrician to do this, he must know how to make a loop in the wire.

Long-nose pliers are used. The end of the wire is clamped between the jaws of the pliers. Then it is rolled around one jaw of the pliers. Since the pliers taper almost to a point, the jaws increase in diameter away from the end. Therefore, the place on the jaws that the loop is made controls its size to fit the diameter of the screw.

Grasp the end of the wire with the ends of the jaws of the pliers. Bend the end slightly. Roll the pliers along and increase the bend a bit. Continue this until the proper size loop is obtained. The loop will look like Figure 6–8*A*, and will not be centered. To center, place the pliers as shown and give them a slight twist.

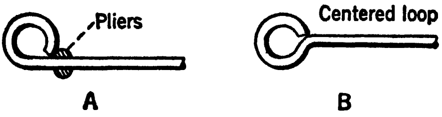


FIG. 6–8. Bending a loop.

The completed, centered loop will look like Figure 6–8*B*.

If the wire is stranded, it should be thoroughly twisted and then tinned — that is, slightly coated with solder — before the loop is begun. Otherwise the procedure is the same as for solid wire.

D. SPLICES

1. PURPOSE OF SPLICE

Some electricians distinguish a splice from a joint. By a *splice* they mean the joining of two stranded wires, and by a *joint* they mean a similar union of two solid wires. We shall not make any distinction here between a splice and a joint. Our definition of a joint or splice is the union of two conductors to make a connection between the two wires which will be both mechanically and electrically secure.

2. SPLICING TECHNIQUE

First remove the insulation from the wires and, in the case of bus bar, remove the enamel. Insulation can be removed by crushing it with the heel of the side-cutting pliers, as in Figure 6–9*A*. Then it is removed by placing the wire between the cutting edges of the pliers, holding the arms firmly, and drawing off the insulation, as in Figure 6–9*B*. Care must be taken not to touch the metal wire.

Next, the exposed wire should be thoroughly cleaned by scraping. A sharp blade should never be used; rather, use the side of the screwdriver blade of the electrician's knife. A wire is not clean until all tarnish and oxidation are removed and the metal is bright. Care must be exercised not to nick the wire, for this weakens the wire and makes it possible for the wire to break too readily.

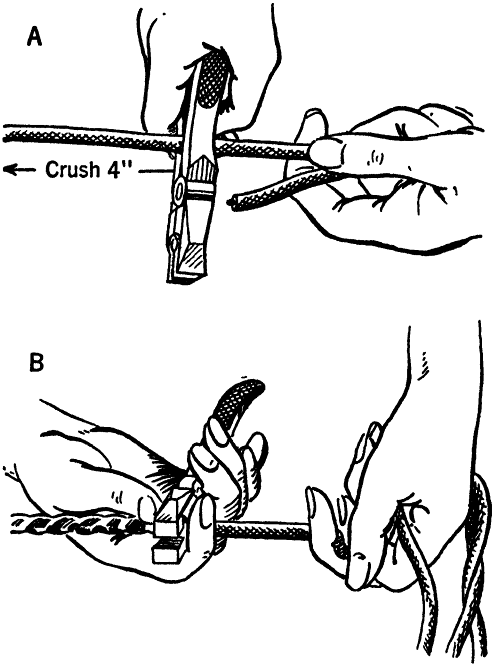


FIG. 6–9. Removing insulation.

Then the splice is made, according to the instructions on pages 336–341. Splices in parallel wires should not be made next to each other. So as to prevent short circuits and decrease the bulkiness and thickness of the wires at the place of splicing, the splices should be staggered at least six inches apart. In this way the splice of one wire lies next to an unspliced part of the neighboring wire. Permanent splices should be soldered so that the parts making contact cannot oxidize and thus in time make poor connections. (In airplane use, however, the Army never considers any line splice to be a permanent connection; every splice, temporary or not, must be removed and replaced by an unbroken, continuous length of wire as soon as possible.)

Finally, holding the wires taut, the electrician tapes the splice as shown in Figure 6–10 to replace the insulation that was removed. This prevents short circuits and makes the splice waterproof. For every splice a double layer of rubber and friction tapes should be used. Beginning at about the center of the splice, the rubber tape should be wrapped to the right until about half an inch of the rubber insulation on the wire is covered, as in Figure 6–10*A*. Then reverse the direction of wrapping until it covers a

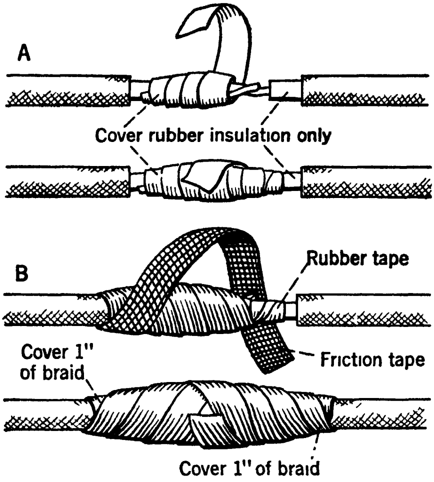


FIG. 6-10. Steps in taping a splice.

half inch of the rubber insulation on the other side of the splice. Wrap toward the center and end the wrapping there. In wrapping, the rubber tape should be stretched and laid tight, each turn of wrapping covering half the previous turn. Note that the final result is that there are two layers of rubber tape on the bare wire of the splice covering half an inch of the rubber insulation of both wires joined by the splice.

Two layers of friction tape should be wound in exactly the same manner that the rubber tape was wound, except that instead of half an inch it should overlap the braiding of both wires for one inch, as in *B*. Roll the taped splice back and forth between the hands several times to help press down and seal the edges of the tape.

3. TYPES OF SPLICES

As we noted before, there are many different kinds of splices. Of these we shall consider only: (*a*) the field-wire splice, (*b*) the Western Union splice, (*c*) the tap splice, (*d*) the flexible-wire splice, (*e*) the field-wire T-splice, and (*f*) the combination seizing-wire splice.

Field-wire splice. This splice provides for good contact between the wires, and at the same time it will resist a great deal of strain. It is used when one pair of wires must be joined to another pair. The steps in making this splice are illustrated in Figure 6–11 and explained below.

(1) Cut the ends of each pair of wires flush and square. The method of cutting wires was explained on page 107.

(2) Measure about 6 inches, or the length of the pliers, on one of the wires in a pair of conductors, and cut off this length. Do the same for a differently colored wire in the other pair.

(3) About 4 inches from the end of each wire in each pair, remove the insulation and clean the bare wires.

(4) Match a long wire of one pair with a short wire of the other pair. The colors of the insulation of the wires in each of these matchings will now be alike.

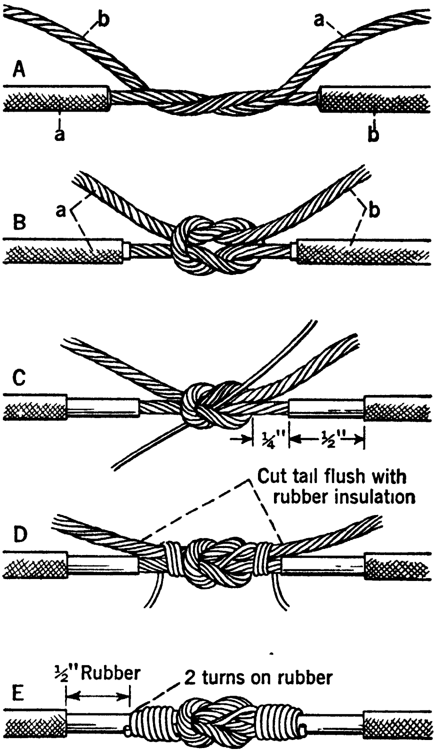


Fig. 6–11. Steps in making a field-wire splice.

(5) Tie together each set of long and short conductors with a square knot. This knot is the same as that used in rope shopwork, explained on pages 382–383. (See Figs. 6–11*A* and 6–11*B*.)

(6) In the same way, tie together the other set of short and long wires. In the center of each knot insert the *seizing wire,* a bare copper wire of small diameter, and pull the knots tight. (See Fig. 6–11*C*.)

(7) Wind the seizing wire around the free end and the main part of the wire. (See Fig. 6–11*D*.) Cut the free ends of each wire flush with the rubber insulation on the short and long wires

and continue the winding until there are two turns on the rubber insulation of the wires. This winding should consist of very tight and very close turns. (See Fig. 6–11*E*.)

(8) Complete by taping.

Western Union splice. This splice is used when joining two solid (not stranded) wires. The steps are illustrated in Figure 6–12 and explained below.

(1) If two pairs of wires must be joined, stagger the splices as was done for the field-wire splice.

(2) Remove the insulation on each wire for about 8 inches. Clean the exposed wire.

(3) Make one complete twist of one wire over the other as in Figure 6–12*A*.

(4) Make three complete turns. (See Fig. 6–12*B*.) This portion of the splice is called the *neck;* it should extend for about 2½ inches.

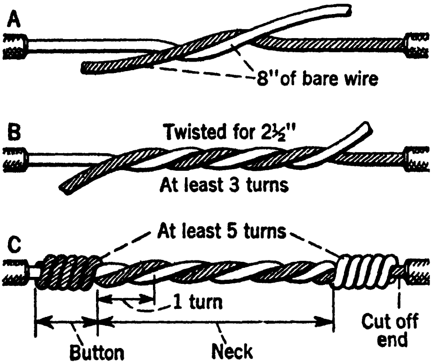


FIG. 6–12. Steps in making a Western Union splice.

(5) At each end wind the wire closely and tightly, making five complete turns. (See Fig. 6–12*C*.) Cut off the extra wire as close as possible; do not leave any sharp points that may later cut or puncture the taped insulation. These two windings at each end of the neck are called the *buttons.* In soldering, the solder should only be placed on the neck, not on the buttons.

(6) Complete by taping.

Tap splice. When it is necessary to join a wire into a permanently installed line without cutting the latter wire, a tap splice is used. It can be used with both solid and stranded wires, and for joining the two types. The steps in making this splice are illustrated in Figure 6–13 and explained on page 339.

(1) Expose and clean about 1 inch of the permanently installed

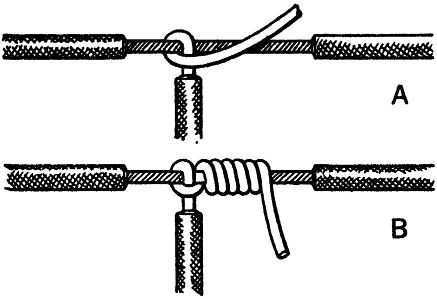


FIG. 6–13. Steps in making a tap splice.

wire at the point where the splice is to be made. Do the same with 3 inches at the end of the other wire.

(2) Lay the loose wire over the permanently installed wire and wind it around the permanently installed wire. (See Fig. 6–13*A*.)

(3) Make 5 complete turns of the end of the loose wire around the permanently installed wire. (See Fig. 6–13*B*.)

(4) Cut off the remainder of this wound wire close to the installed wire, making sure that the end is not sharp or pointed so that it will cut or puncture the insulation taping.

(5) Finish by taping.

Flexible-wire splice. This splice is used to make a joint which will stand tension in flexible stranded wire. It is similar to the field-wire splice and is illustrated in Figure 6–14.

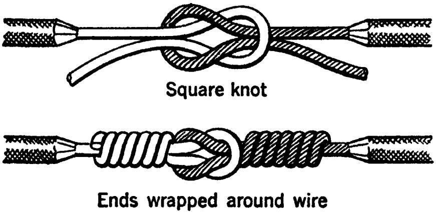


FIG. 6–14. A flexible-wire splice.

(1) Prepare the wires as for a field-wire splice, and tie them with square knots.

(2) Instead of using seizing wire as in the field splice, wind the ends of the wires coming out of the knots closely and tightly around the main wire.

(3) Finish by taping.

Field-wire T-splice. To tap a permanently installed line without interrupting service, the field-wire T-splice is used. For example, communication with troops at point *A* has been established, and must be maintained. But the troops are moving to point *B*, and it is necessary to establish communication there too. A circuit is added to the line, using the field-wire T-splice, to establish contact with point *B*. Contact with point *A* is not interrupted. When troops have left point *A*, that part of the wire may be cut, leaving service to point *B*.

This splice is seized and taped in the same way as other field-wire splices. The steps are illustrated in Figure 6–15 and listed below.

(1) Remove $1\frac{1}{2}''$ of the insulation, as shown in Figure 6–15*A*, from the conductor at *A*; and about a foot away, at *B*, do the same. These may be considered the two wires of the main line.

(2) The wires Y_1 and Y_2 compose the circuit to be added to X_1 and X_2. Cut off about 1 foot of Y_1. (See Fig.6–15*B*.)

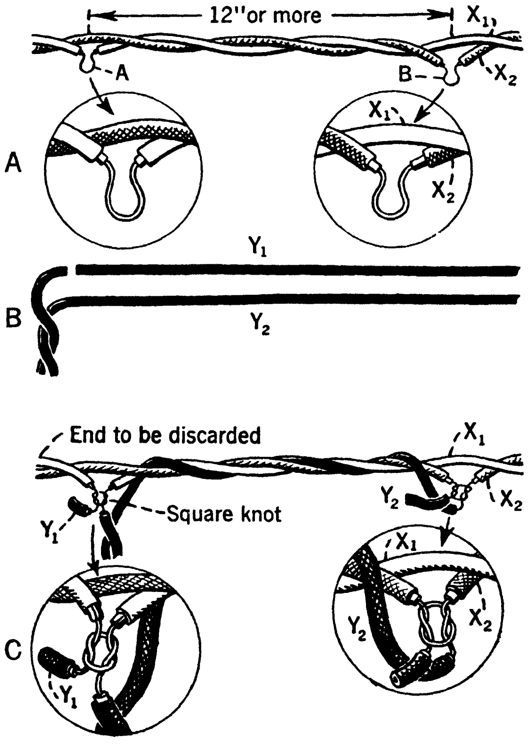


FIG. 6–15. A field-wire T-splice.

(3) Trim the ends of Y_1 and Y_2 of insulation and clean the wire.

(4) Twist wire Y_2 over X_1 and X_2, as shown in Figure 6–15*C*.

(5) Make a square knot joining X_1 with Y_1, and a square knot joining X_2 with Y_2

(6) Finish each splice with seizing and rubber and cloth tape.

Combination seizing-wire splice. At times a stranded, insulated conductor must be attached to a solid, uninsulated wire. For this a combination seizing-wire splice is used. The steps in making it are shown in Figure 6–16 and explained below.

(1) Expose and clean about one inch of the stranded, covered wire. Clean the area on the solid bare wire where the splice is to be made.

(2) Place the cleaned stranded wire on the solid wire, as in Figure 6–16*A*.

(3) Wind at least four turns of seizing wire on the solid wire back of the insulation of the stranded wire.

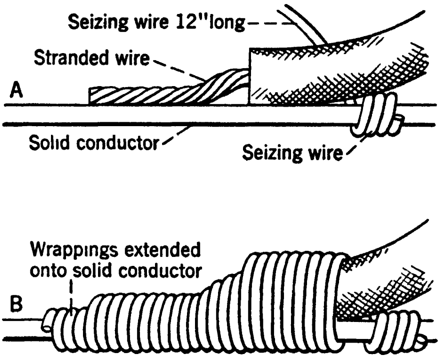


FIG. 6–16. Steps in making the combination seizing-wire splice

(4) Bring the seizing wire over the insulated part of the stranded wire and continue winding closely and tightly around both the insulated part of the stranded wire and the bare solid wire. Then continue winding around both bare stranded wire and bare solid wire. End the winding with at least four turns around the solid wire alone. (See Fig. 6–16*B*.)

(5) Since the stranded wire will come out with the least pull, care must be taken that it is not placed under a strain. As protection, at some spot near the splice the stranded wire should be tied to some immovable object to prevent any strain from being placed on it.

E. WIRING AND WIRE SPLICING SKILLS AND KNOWLEDGE

As a brief review of what you have learned about wiring and wire splicing you may consult the following table which lists a number of the things you have learned to do and the skills which are necessary to do them well. As a test of your ability and as a means of fixing the various processes in your mind you may wish to carry out some of the suggested jobs, projects, and exercises. The numbers after each item give the pages on which that topic is discussed.

Things You Should Be Able To Do	Things You Should Know	Suggested Jobs, Projects, and Exercises
Make a soldered butt joint with bus wires, 326–327.	How to nick and break solid wires with side-cutting pliers, 107. How to solder wires, 326–341.	Resolder broken or loose butt joints.
Make a bus-wire loop joint, 327–328.	How to make tight joints, 309-310.	Replace a bus wire.
Attach lugs to ends of wires, 329–331.	How to sweat lugs to wires, 328–329.	Make a cable with lugs on each end (battery cable).
Solder wires to terminal punchings, 331–333.	How to use a minimum amount of solder, 329–330	Replace wires on terminal punchings.
Make a field wire splice, 336-338.		
Make a Western Union splice, 338.	How to determine the correct number of turns required on each side of the splice for maximum strength. (Western Union splices are the most commonly used, 337–338.)	Join four lengths of wire to make two lengths with the Western Union splices staggered.

Things You Should Be Able To Do	Things You Should Know	Suggested Jobs, Projects and Exercises
Make a tap splice, 338–339.	How to wrap rubber and friction tapes over a soldered splice, 335–336.	Tap wires to a main line for temporary lights.
Make a splice with flexible wires, 339.	How to remove insulation without cutting or nicking the strands, 334.	Replace or reconnect broken flexible wires to a microphone or telephone head set.
Make a combination seizing wire splice with a solid wire and a flexible wire, 341.	How to protect the splice to prevent constant bending from breaking it, 341.	

SUMMARY

1. All electrical machines must have conductors — wires for the passage of the electrical current. Conductors are also needed to bring electrical power to homes and factories, to carry electrical impulses to telephone and telegraph sets, to operate radio transmitters and receivers, moving-picture projectors, and so on.

2. Bus wire or bus bar is used when it is necessary for internal conductors and connections in electrical equipment to be strong and rigid, as in electrical control boards and radio sending and receiving sets.

3. The butt joint is generally used only with square bus wire. The loop joint is generally used with round bus wire.

4. The terminal is the connection which is made between an electrical apparatus and the external wiring circuit.

5. You may attach wires to an electrical apparatus by forming a loop, holding the loop in place with a screw, and using lugs and terminal punchings.

6. Cables and wires that end at power boards and other apparatus are often attached by means of cup lugs or clamp lugs.

7. Terminal punchings or punched terminals are terminals which are small or stamped from a flat sheet of metal.

8. Electrical connections may be made by loop bending, which is bending a wire around a screw and tightening it.

9. The union of two conductors to make a perfect mechanical and electrical connection between them is called a joint or splice. There are many kinds of splices, including the field-wire splice, the Western Union splice, the tap splice, the flexible-wire splice, the field-wire T-splice, and the combination seizing-wire splice.

10. The field-wire splice is used when one pair of wires must be joined to another pair.

11. The Western Union splice is used when joining two solid (not stranded) wires.

12. The tap splice is used to join a wire into a permanently installed line without cutting the latter wire.

13. The flexible-wire splice is used to make a joint which will stand tension in flexible stranded wire.

14. The field-wire T-splice is used to tap a permanently installed line without interrupting service.

15. The combination seizing-wire splice is used to attach a stranded insulated conductor to a solid, uninsulated wire.

How many of the following terms and phrases can you define or explain?

Conductor
Bus bar
Spaghetti
Butt joint
Loop joint
Terminal
Terminal punchings
Lugs
Sweating
Insulator
Flux
Loop bending
Splice
Joint
Neck

SELF-TESTING EXERCISES

Answer These Questions

On a separate sheet of paper numbered from 1 to 6 write the letters for the phrases that answer the following questions correctly.

1. Which splice would you use if you wished to join one pair of wires to another so as to make a good contact between them and one which would

resist a great deal of strain? (*a*) The field-wire splice; (*b*) the Western Union splice; (*c*) the combination seizing-wire splice; (*d*) the field-wire T-splice; (*e*) the tap splice.

2. Which splice would you use if you wished to join two solid (not stranded) wires? (*a*) The tap splice; (*b*) the flexible-wire splice; (*c*) the field-wire T-splice; (*d*) the Western Union splice; (*e*) the combination seizing-wire splice.

3. Which splice would you use if it were necessary to join a wire into a permanently installed line without cutting the latter wire? (*a*) The field-wire splice; (*b*) the Western Union splice; (*c*) the tap splice; (*d*) the combination seizing-wire splice; (*e*) the flexible-wire splice.

4. Which splice would you use if you needed to make a joint which would stand tension in flexible stranded wire? (*a*) The tap splice; (*b*) the flexible-wire splice; (*c*) the field-wire T-splice; (*d*) the Western Union splice; (*e*) the combination seizing-wire splice.

5. Which splice would you use to tap a permanently installed line without interrupting service? (*a*) The combination seizing-wire splice; (*b*) the Western Union splice; (*c*) the field-wire T-splice; (*d*) the flexible-wire splice; (*e*) the tap splice.

6. Which splice would you use to attach a stranded, insulated conductor to a solid, uninsulated wire? (*a*) The combination seizing-wire splice; (*b*) the Western Union splice; (*c*) the field-wire T-splice; (*d*) the flexible-wire splice; (*e*) the tap splice.

COMPLETE THESE STATEMENTS

On a separate sheet of paper numbered from 1 to 15 write the words needed to fill correctly the blank spaces in the following sentences

Bus wire is No. (1) gage, or heavier, copper wire. The butt joint is generally used only with . (2) bus wire. The loop joint is generally used with (3) bus wire. The butt joint is (4) than the loop joint. Cables and wires that end at power boards and other apparatus may be (5) into terminal cup lugs for attachment. When you are fastening a clamp lug, the clamps must be fastened tightly around the . (6) part of the conductor. If there is the slightest danger of short-circuiting, the exposed clamps of the lug should be (7) . In soldering, lumpy joints should be avoided because they offer too much . . (8) . . Half and half solder has only . (9) the conductivity of copper. Of the two methods of soldering splices . (10) . . is preferred. When several punchings are employed they must be held in place by a . . (11) . . . Wires are led in on the . . (12) . . side and under their respective punchings. You may remove insulation by crushing it with the heel of the . . (13) . . .

In airplane use the Army never considers any line splice to be a . . (14) connection. A splice should be . (15) . . in order to prevent short circuits and to make it waterproof.

Are These True or False?

On a separate sheet of paper numbered from 1 to 5 write a T *or an* F *to show whether each statement is true or false.*

1. Insulation should be cut back some distance beyond the lug.
2. When soldering wire to a terminal you should place the solder just on the spot where it belongs.
3. Corrosive fluxes may not be used in electrical work.
4. The electrician uses short-nose pliers to make a loop in wire.
5. A wire is not clean until all tarnish and oxidation are removed and the metal is bright.

QUESTIONS

1. Why is bus wire particularly important in short-wave radio sets?
2. Why is bus wire often coated with a thin layer of tin?
3. Why must bus wires be properly spaced from one another?
4. Why should wire not be pretinned if it is to be used with the type of lug that has a small hole?
5. Why are clamp lugs stronger than cup lugs?
6. What other advantage do clamp lugs have over cup lugs?
7. Why should you avoid making a rosin joint?
8. Why is sweating the small terminals of radio and telephone apparatus not advisable?
9. Why must you be careful not to nick the wire when removing insulation?
10. What are the eight steps in making a field-wire splice?
11. What are the five steps in making a Western Union splice?
12. What are the five steps in making a tap splice?
13. What are the three steps in making a flexible-wire splice?
14. How would you make a field-wire T-splice?
15. What are the five steps in making a combination seizing-wire splice?

VII

Ropes, Splices, and Knots

INTRODUCTION

If ever there is a Hall of Fame for materials and tools, rope will certainly have an honored place in it. It is said that man first showed his intelligence when he began to use the materials of his environment to improve his living conditions and lighten his daily labors. Rope was one of the earliest materials he used.

The earliest kinds of rope. Thousands of years before recorded history man began to make and use rope. When our ancient ancestors saw the need for dragging, lifting, and tying things together, rope was the solution. But the rope used then was not the kind that we commonly see today. Even today, however, such primitive ropes are still used by barbarian tribes in the untraveled regions of the earth and by military forces and explorers in an emergency.

The earliest ropes were made of materials near at hand and easy to get, such as long vines, strips of animal hide, and dried animal intestines. When the need arose for stronger and longer ropes, early man learned to twist, weave, and braid his rope materials into thicker and longer ropes. But rope is useless for binding, dragging, or lifting unless it can be tied. Tying means knotting, and when these ancients invented rope they also invented knots.

Real proof of how ancient rope is, can be found in museums today. Rope made of flax fibers (from which linen is made), papyrus, or animal hides has been found on Egyptian mummies embalmed 4000 years ago. The Incas of Peru used rope for making nets. Too, the Incas and the ancient Chinese, having no writing systems, used knotted ropes to keep their records and accounts. Even today Peruvian shepherds still use knotted rope for this purpose.

Rope today. How would history have been affected if man had not been able to invent the sailing vessel because he did not know how to make rope? How long would the settlement of the West have been delayed if our early American pioneers had not had rope? Could the first skyscrapers, bridges, and other large construction projects of man have been accomplished without the derrick, hoist, wheel, and pulley — and the rope they require? How many lives have been saved because the surgeon was able to sew up wounds and tie up arteries with fiber or gut, a form of rope? How would mountain climbers or troops in the field span deep rivers and chasms without rope? What would the soldier do for his tent or the sailor for his ship, without rope?

Rope is one of the important items in preparing for a Commando raid. It is an essential in almost all emergency equipment, such as the rubber boat and parachute of our air fighters and the life rafts of a ship, and it has an important place in the packs of many soldiers. In equipping just one battleship or light cruiser, almost seven miles of rope are used; one destroyer uses two miles of rope. If a full list were made of the different places and uses for rope, very few occupations or industries could be omitted.

A. TERMS

1. TERMS USED IN MANUFACTURE

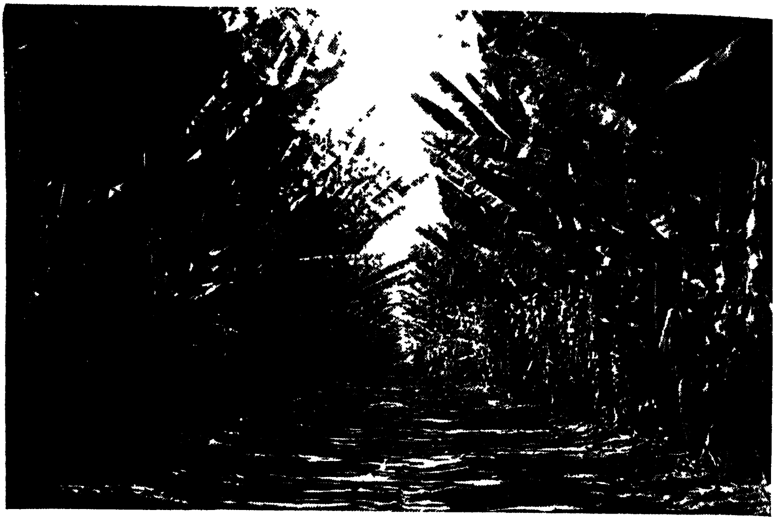
The materials of manufacture. In general, there are two kinds of rope: that made of *plant* fibers and that made of *metal* in the form of twisted strands or wire. Vegetable rope has always been in far greater use than metal rope. Fiber rope can be worked to a greater degree and in more ways than metal rope. For these reasons we shall here consider only fiber rope; and of the many varieties, we shall study only those most commonly used.

What fiber is. *Fiber* is the fine, threadlike material of which many living things are composed. If you look at a piece of cotton under a microscope or magnifying glass, you see that it consists of many hairlike things, long and short, intertwined and interwoven. These are cotton fibers.

Hemp. There are thousands of plants whose fibers can be used in making rope. Of these, *hemp* is the one most commonly used. It belongs to the same plant family as flax. Before World War II, Italy produced the best hemp fiber; it was used in the United States for commercial twine, carpet yarns, and coarse toweling. Hemp rope has a light golden color throughout and is strong and long wearing; but it is expensive. *Tarred hemp,* not a black rope as its name would suggest, is thinly covered with light tar oil which makes it even stronger.

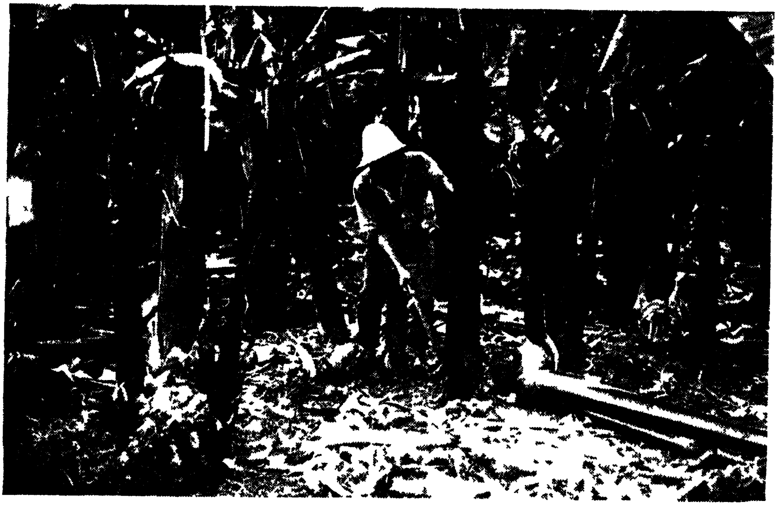
Manila hemp. Considering cost, strength, and wear, rope made of manila hemp, which comes from the Philippine Islands, is the best for all-around use. It is essential for all marine work and for such industrial purposes as oil wells and construction work. It cannot be replaced by other fibers because manila-fiber rope will stand a greater strain than any other rope of equal size. It will last longer under rough usage. It has such superior stretching qualities that it will stand sudden shocks which would break chains and other ropes, even those made of wire. Since it swells little when wet, it is excellent for marine uses, especially when it must be drawn through pulleys. Manila fiber is one of the fourteen strategic materials; that is, materials like rubber and silk which are absolute necessities for winning a war, which must be imported because they cannot be produced in this country, and for which no favorable substitute can be found.

Manila hemp is not really a hemp; rather, it comes from the *abaca* plant, which belongs to the banana family but does not produce fruit. (See Fig. 7–1.) From its soft, spongy stem or stalk, fibers 8 to 10 feet long are obtained. When the plant is about three years old it is cut down and split into strips about two inches wide. (See Figs. 7–2 and 7–3.) The pulp is scraped off and the long, shiny, white fiber is ready for export. New manila rope is smooth, soft, pliable, shiny, and brownish yellow in color. Worn-out manila rope is ground up and used to manufacture strong manila paper and cardboard.



Courtesy Columbian Rope Co

FIG. 7-1. Full-grown abaca.



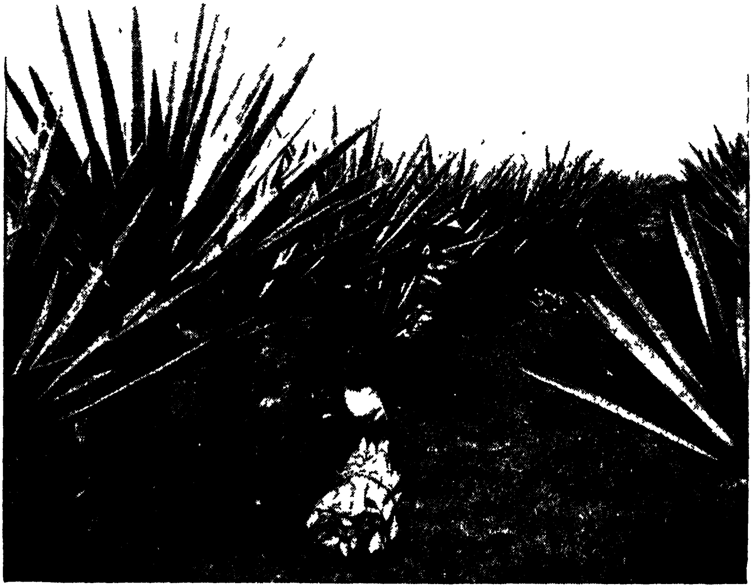
Courtesy Columbian Rope Co

FIG. 7-2 Cutting down abaca stalks.

Courtesy Columbian Rope Co

FIG 7-3 Stripping abaca fiber

Sisal. *Sisal,* also called *henequen,* comes from the long, tough fiber in the heavy leaves of a plant that grows principally in Yucatan, Mexico. (See Fig. 7–4) All of it is exported, especially to this country and Canada, and manufactured into binder twine for the wheat fields and a cheaper but poor substitute for manila rope. Sisal rope has poor wearing qualities when exposed to damp weather or when used in water. It is only half as strong as manila rope. Sisal rope is stiff, rough, dull-looking in appearance, yellowish white and sometimes greenish white in color.



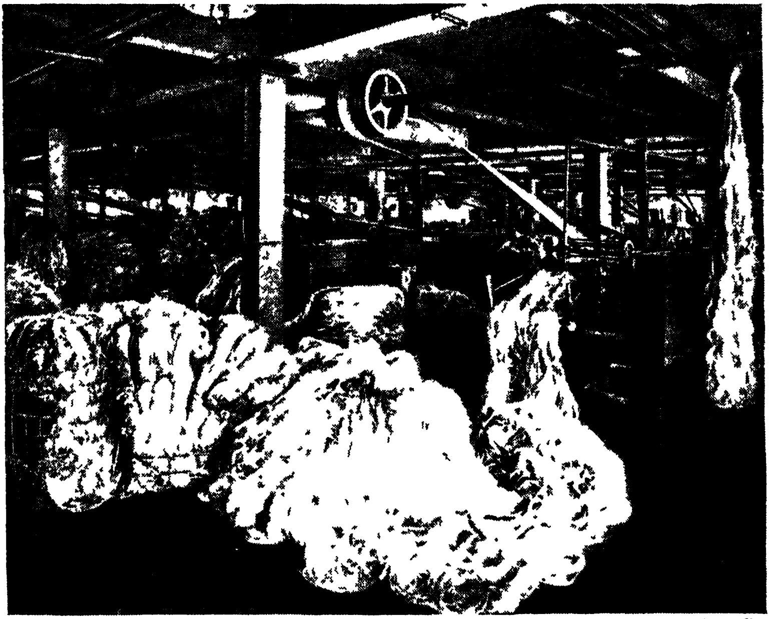
Courtesy Whitlock Cordage Co.

FIG. 7–4. Full-grown sisal.

Coir. From the thick, spongy covering which protects the coconut from breaking when it falls from the tree to the ground, comes *coir* fiber. Coir rope is a rough, red rope, about one-third the weight and one-fourth the strength of hemp rope of the same size and of much poorer wearing qualities. When new, it is elastic and floats on water. With age it loses all of its good qualities.

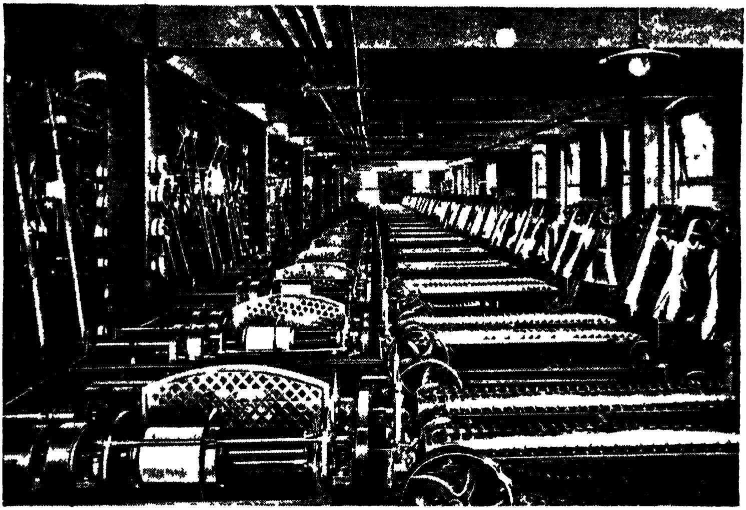
Rope and friction. Good rope in common use consists of nothing but plant fibers twisted together and held in place by *friction.* This is the same friction studied in the science classroom, the resistance or grasp between two surfaces. Naturally, when the fibers are twisted there is a tendency for them to untwist; but this very fact is used, as it will be explained later, to make a nonraveling, untwisting rope. However, it should be noted that some ropes, like window sash or washline cord, may be made in other ways, as by plaiting (braiding), and do not depend entirely on the friction of twisting

Steps in the manufacture of rope. First the cleaned fiber is thoroughly combed out and stretched to form a thin, weak, continuous band about two inches wide called a *sliver.* (See Fig. 7–5.)



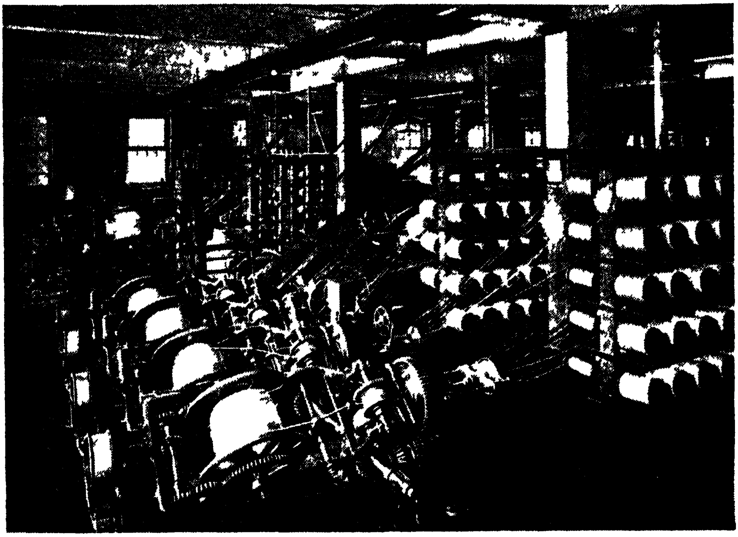
Courtesy Whitlock Cordage Co.

FIG. 7–5 Combing and stretching fibers to form slivers.



Courtesy Whitlock Cordage Co

FIG 7–6 Spinning slivers to form yarn



Courtesy Whitlock Cordage Co

FIG 7 7 Strands are laid to form rope.

The sliver is *spun* (twisted like wool, cotton, and silk fibers for textiles) to form the *yarn*. (See Fig. 7–6.) Then the required number of yarns are twisted into *strands* in the former. Finally, the required number of strands are *laid* (twisted) by a machine called a *layer* or *rope walk* and *laid* (twisted) to make the rope. (See Figs. 7–7 and 7–8.)

It is most important to note that each step in twisting is done successively in the opposite direction. Thus, fibers twisted to the *right* make yarns or threads. These are then twisted to the *left* to make strands. Finally, these strands are twisted to the *right* to make the rope. In this way, by friction and resistance from successive opposite twistings, a strong, tight, nonraveling rope is manufactured. If this succession of opposite windings were not made or, to put it another way, if fibers, yarns, and strands were all twisted in the same direction, they would untwist and separate when the least strain was placed on the rope. However, with rope parts actually being twisted in opposite directions, strain on the rope only makes its parts tighter and stronger.

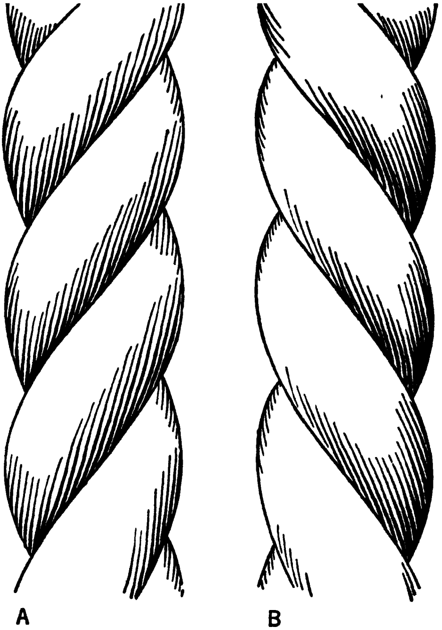


FIG. 7–8. Right-laid rope (A) and left-laid rope (B).

The lay. *Lay* is the direction in which the strands are twisted to form the rope. This may be right or left, and according to this, ropes are called, respectively, *right-laid* (*right-handed*) or *left-laid* (*left-handed*). To decide in which group a rope belongs, hold it up and observe in which direction the strands are twisted. If they slope from upper right to lower left, it is right-laid. If they slope from upper left to lower right, it is left-laid. (See Fig. 7–8.)

With the lay or *against the lay* describes a direction, respectively, following with or contrary to the lay of the strands of the rope. Lay may also describe how tight the strands are twisted, as soft, medium, common, plain, or hard lay.

Names and sizes of ropes. All sizes of ropes, from the smallest to the largest, are called *cordage*. However, different names are applied to different sizes. Sizes are usually given by the circumference, the distance around the outside of the rope. Those that are less than 1¾ inches in circumference are called by various names, as *small stuff*, *small cordage*, *cord*, or *twine*. The sizes of these small cords are usually given by the number of yarns or threads of which they are made, 24 threads being the largest.

Ropes are larger than 1¾ inches in circumference. They are usually sold by weight and length in fathoms. A fathom equals 6 feet.

Plain-laid rope consists of three strands twisted left or right, usually right. Four-stranded rope is plain laid with four instead of three strands. However, laying four strands will make a hollow center throughout the length of the rope. This is bad because such rope will not have the usual round shape and will not be so strong as solid rope. To overcome these poor features, the empty center space is filled in, while laying, with a small rope known as the *heart*. The heart is not twisted; the strands are laid around it.

A *hawser* is any rope 5 inches or more in circumference.

Cable-laid or *cable* consists of three ropes laid together to form a rope of larger diameter.

Strength of rope. Various manufacturers claim different strengths for their products. The strength of *hemp* rope up to 6 inches in circumference can be approximated by using the following formulas.

Breaking strain. The amount of pull, stretch, or strain a rope will stand before it will separate or break is called *breaking strain* (*B.S.*).

$$B.S. = \frac{C^2}{3} = tons$$

This means that the breaking strain equals the circumference of the rope squared (C^2), and the result divided by 3. The answer gives the number of tons of strain which this particular size hemp rope will take before it will snap or break. Applying this formula to a rope 2 inches in circumference, we find:

$$B.S. = \frac{2^2}{3} = \frac{4}{3} = 1\tfrac{1}{3}\ tons$$

In other words, a hemp rope 2 inches in circumference will break when strained by a force of $1\frac{1}{3}$ tons or greater.

Working strain. For safety and to avoid destroying the rope, however, it is seldom strained to its breaking point. It should not be used beyond its working strain, which is figured thus:

$$W.S.\ (working\ strain) = \frac{C^2}{9} = tons$$

Safe working strain. Even then, especially because of safety and the fact that rope does become weaker with age and use, care should be taken not to pull, stretch, or tug on it beyond its safe working strain. The formula for hemp rope is:

$$S.W.S. = \frac{C^2}{18} = tons$$

We have already noted that the above formulas apply only to hemp rope. Ropes made of other fibers have different formulas. For example, the formula for the breaking strain of coir rope is:

$$B.S. = \frac{C^2}{12} = tons$$

The safe working strain of manila rope is figured according to the formula:

$$S.W.S. = \frac{C^2}{7} = tons$$

Compare these formulas with the formulas for hemp rope and the difference in strength of different rope fibers will be clearly seen.

2. TERMS USED IN HANDLING ROPE

Some of the terms used in handling rope are explained below and in Figure 7–9, others you have already learned, and still others will be explained throughout the chapter. It is most important to note that several terms may mean the same thing and that one knot may be known by several different names.

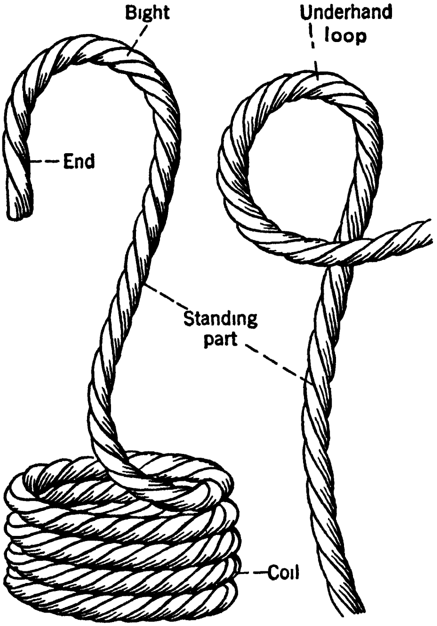


Fig. 7–9. Some rope terms.

The *standing part* is the long end, or greater part of the rope. When a knotted rope is in use, it is the part that receives the stretch or pull.

The *end*, *running part*, *fall*, or *fall line* is the short free end which is generally handled most in making knots.

The *bight* is the bend formed by placing the end and the standing parts next to and parallel to each other. This term will be further explained in the discussion of rope splices.

The *loop* or *turn* is the eye or circle formed when the end crosses over the standing part and they point in opposite directions. If the standing part is below the end, it is an *underhand loop;* if above, it is an *overhand loop*.

A *round turn* or *bend* is any turn in a rope around itself or around some other object.

Haul is the pull on a rope.

Taut is a tight haul or rope under tension.

Hitch is to attach a rope to an object in such a way that it can be easily and readily detached.

A *half-hitch* is a turn of a rope so arranged that a section of the turn will bear, or press, on another section of the turn.

Knots are various combinations of bights and loops so arranged that the tight part of the rope will bear on the free end. They make ropes *hold.* A knot in manila rope reduces the strength of the rope by as much as 20 per cent.

B. GENERAL CARE OF ROPE

The proper care of rope is extremely important. There can be no question that reputable rope manufacturers make good rope. Then what is it that makes good rope become poor and weak? The answer is improper care and use.

Good care and use of rope is one of the best protections against loss of life, limb, and money in any operation where rope is used. Think of the tremendous weights and power that rope must resist in building a skyscraper, a bridge — in any great construction job! Picture the possible results when in the midst of operations a rope breaks because it had poor care and use! Military campaigns may fail because reserve forces cannot be brought up; improper care of the rope used to build an emergency bridge might cause the bridge to break, resulting in the death of many men and preventing the required reserves from coming up.

Many situations can be described showing the danger and damage that may result from poor care and use of rope. Remember, when you read stories of industrial disasters and military and naval failures, that usually only immediate causes are given. Often, however, these may have been due to such things as the failure of rope somewhere in the background.

As explained before, manila hemp is one of the strategic materials; therefore, consider the fact that if we could, with proper care and use, increase the life of the rope now in use in this country by a mere five per cent, it would be the same as increasing our rope stocks by eight million pounds.

1. INSPECTION

Internal examination. The inside yarns of rope are the first to show wear and rot. Open up the lay of the rope at three-foot intervals. If the color inside is different from that of the outside and its fibers are broken and powdery, the rope is in poor condition. The next time it is used, even a small load may break it. If the inside is dark brown or greenish in color, the rope is entirely useless.

Mildew and bacteria. You may have seen a greenish or blackish covering on white bread that was stored in a warm, damp place. This was fungus or mold. Mildew is a form of microscopic fungus that attaches itself to other things, especially plants, and feeds and grows on them. Thus, mildew on a rope made of plant materials will feed on the fibers and eventually weaken the rope.

Bacteria are the microscopic living things that cause oxidation, souring of milk, illness of animals, and so on. Bacteria, being living things, must eat; and some of them particularly like a diet of plant fibers, such as those of which ropes are made. Naturally, when they eat away the walls that hold the fiber material together, the rope is greatly weakened.

Thus, in general, rotten rope is due to the action of mildew and bacteria. However, with proper care, mildew and bacteria can be stopped from attacking rope fibers and, therefore, rope need not rot.

Chemical protection. We have already briefly explained that the life and strength of rope can be extended by tarring the fibers to prevent rot. Today different manufacturers use various methods to accomplish the same end. Oils, graphite (a natural, oily carbon), and chemicals are employed. Basically the purpose is to keep away any excess moisture from the fibers and to hold in the moisture they normally contain. Some of these treatments also act as poisons to bacteria and mildew, and so stop their growth. Oils and graphite also serve as lubricants for the ropes, especially if they must run through tackle or around drum reels.

With time and use, ropes treated with oils and graphite tend to lose their protective coating. This should be renewed when necessary. Some manufacturers, however, claim that for their particular rope this is not possible, for the oils and chemicals must be impregnated into the fiber during the manufacture of the rope.

2. COILING

Rope is usually shipped in coils, carefully wrapped in burlap or some other protective covering. A *coil of rope* is a many-layered ring of rope wound spirally. Coils of new rope are usually 200 fathoms (1200 feet) long. In coiling rope, the direction of making the rings or spirals (that is, whether it should be clockwise or counterclockwise) depends on whether the rope is right or left. If right-laid, coil right-handed, or clockwise; if left-laid, coil counterclockwise. This is important, for to coil incorrectly will tend to untwist the rope and thus weaken it.

If a rope is full of kinks and turns, coil *against* the lay, that is, left-handed for a right-handed rope. Then bring up the fag end of the first spiral through the center of the coil and start a new coil *with* the lay. If such a rope has many turns, coil small; if a few, coil large.

If one end of such a rope is attached to something and must not be undone, begin coiling left-handed with the part where it is tied. When this left-handed coil is finished, push the last end through the center of the coil, turn over the coil, and continue as before. *Thoroughfooting* is the name applied to straightening out, unkinking, and coiling rope.

3. UNCOILING ROPE

To uncoil rope, the binding cords that hold the burlap must be carefully cut to free the burlap. This is opened up and laid flat on the floor, exposing the rope.

The *front* of a coil is that side on which the two fag (frayed) ends of the coil usually show. The *rear* of the coil is the opposite side. If the fag ends are not on top, turn over the coil so that the front side faces up and is resting on the rear side. One fag end marks the very last and outermost ring or spiral of the coil. The other frayed end is the first or beginning ring in the center of the coil. Sometimes this is located on the rear side and it must be drawn through the empty center space of the coil and be brought to the front side.

To uncoil the rope, pull the fag end of the beginning or inside spiral of the coil. (See Fig. 7-10.) Never start to uncoil by pulling the fag end of the last or outermost spiral. By pulling the inside end, the uncoiling is opposite to the direction of turn (the direction the rope was coiled). This removes the turn of the rope and prevents kinking. Pulling the outside spiral will increase the turn of the rope and cause the rope to kink, bend, and tangle. For the same reasons, never try to uncoil a coil that is rear side up.

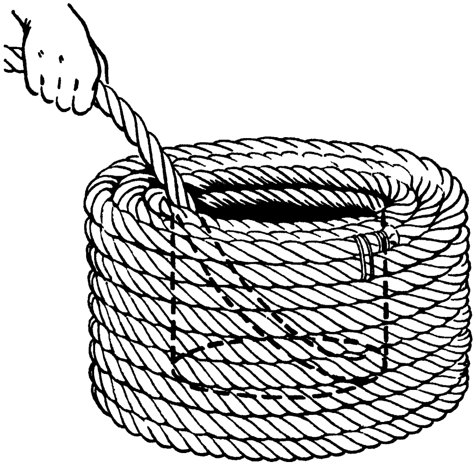


FIG. 7-10. Uncoiling rope.

The instructions given here are so important because so much expense and trouble are caused by wrong uncoiling. The

Boston Navy Yard specifies that on all rope the inside fag end should always be brought to the front through the center and, further, that it be tagged with a card bearing these words: "Draw from this end."

4. TRANSPORTING

Everything that applies to the proper care of rope applies to the transportation of rope. Rope should never be stored or transported uncoiled. It should be coiled and hung up or reeled. Care should be taken that sharp tools and heavy machinery do not crush it.

5. STORING

Since dampness is such a great enemy of rope, proper storing, or *stowing*, is important. Never stow new or used rope until it has been thoroughly dried. Never cover rope so that its moisture cannot escape. Always store rope in a fairly dry, unheated place with circulating air, for heat and extreme dryness are also enemies of rope and they may cause dry rot. Never store rope in a furnace room or other overheated place. Never dry rope rapidly by winding it around a hot boiler or draping it over a hot radiator. Too rapid drying will make rope fibers brittle and easily broken. Never let rope lie tangled on the floor. Coil it loosely and place it on a wooden grating resting on the floor or hang it from a wooden peg. Never hang rope on an unpainted or rusting iron hook. In drying rope, try to keep it stretched out in long lines, preferably resting on a series of wooden pegs.

6. PROPER USE OF ROPE

Mechanical injury. Washlines should always be left slack (loose), especially after a rain or during the night when dew forms. The reason for this is that most ropes, especially those that are untreated, shrink in length when wet. A *taut* rope, one that is under a strain, has this strain greatly increased when it is wetted because shortening its length is the same as increasing the pull on it. Therefore, when possible, always leave ropes slack that have been or are exposed to wetness or dampness.

Working strain. Whenever possible, keep the strain on a rope below the safe working strain (*S.W.S.*). Avoid exposing it to the working strain (*W.S.*) and certainly never expose it to the breaking strain (*B.S.*). (See pages 356 358.) This is especially true for rope that has already seen much use or that once was exposed to a great strain; for regardless of friction, each time a rope is used or greatly strained the fibers tend to slip, and some will even break. All this tends to weaken any kind of rope. Remember that sudden jerks on rope are the same as overstrain for a brief moment.

Avoid kinking. Kinking means making extra twists and sharp bends, and tangling the rope in general. Recall how carefully the strands of rope are laid Loosening the lay or separating the strands because of kinks greatly weakens rope. Never put a strain on kinked or tangled rope. Remember that wet rope kinks more easily than dry rope. Incorrect coiling and uncoiling will cause kinks. Always keep in mind the fact that the strength of a rope at a kink is reduced 20 to 30 per cent below that of an unkinked part.

Knots weaken ropes, especially if the proper knot is not used for the particular purpose at hand. Splices are much better and stronger than knots for permanently joining two lengths of rope. Knots and splices will be considered in more detail later.

Keep rope clean. Keep rope free from sand and grit. Sand and grit work into the rope and act like sandpaper or emery cloth in thinning and breaking rope fibers. Do not drag rope over the ground or over a sharp, rough surface. When possible, tie rope on a round object, not on one with sharp edges. Do not let one line of rope rub against another, because one acts as a rough surface for the other. Never permit the rope to slip on a power-driven winch or to idle against moving parts of machinery.

Avoid sharp bends. When rope is used in a block or pulley, make sure that the sheaves (grooved wooden wheels) have a sufficiently large diameter and that there is clearance between the sheaves and the shell (outside framework of the block). If the sheaves are too small, they will cause the rope to bend too sharply. This will squeeze together the inside fibers of the rope and cause internal friction which alone is one of the greatest weakening agents for rope. Indeed, it is to avoid this, even in normal use, that rope is lubricated with oil or graphite. Lack of clearance will cause the rope to be rubbed and cause friction.

Avoid frozen rope. A frozen rope is a stiff one. Its fibers can be broken more easily than toothpicks. The ice particles act like knives in cutting the fibers. Never use a frozen rope. First thaw it out and thoroughly dry it.

Cut properly. Before cutting a rope, wind a strip of adhesive or insulating tape around it. Then cut through the center of the tape. If a sharp knife is used, this will make a clean cut. The tape will hold the fibers and strands together. To prevent the strands from ever untwisting, the ends should be *whipped,* a process which will be explained on pages 367–370.

Use the proper rope. Always use the proper size, lay, and type of rope for the particular job on hand. Examine rope regularly. Cut out worn sections and splice together the good ends. The following table shows the working strain for new *manila* rope. If the rope has been in use for more than half a year, then each of the loads given must be divided by two. Formulas for figuring similar strains for hemp and coir rope are given on pages 356–357.

Diameter in inches	Breaking point in pounds, for new rope	Safe working strain in pounds for new rope
$\frac{1}{4}$	700	200
$\frac{3}{8}$	1,450	400
$\frac{1}{2}$	2,450	700
$\frac{5}{8}$	4,000	1,100
$\frac{3}{4}$	4,900	1,400
1	8,200	2,300
$1\frac{1}{4}$	12,500	3,000
$1\frac{1}{2}$	17,500	5,000

Chemical injury. Acids are among the great enemies of rope. Indeed, one rope manufacturer absolutely forbids any acid to be brought into his factory at any time. Fibers are very fragile, and even weak acids easily "burn" them. Rope need not be in direct contact with the acid to be affected by it; even acid fumes in the air will eat away rope fibers. Rope affected by acid is off color and its fibers and threads can easily be crumbled with the fingers.

In a similar fashion, alkalies in the form of strong soaps, washing soda, and ammonia are enemies of all rope.

Drying oils, such as linseed oil, and paints make ropes brittle and stiff and therefore easily broken.

Rope exposed to salt water should be thoroughly washed with fresh water to rid it of the salt before it is dried for stowing. Keep rope away from iron rust, which has a chemical action that is very harmful.

Sunlight, besides overdrying rope, produces a chemical action which will discolor rope and weaken its fibers.

Increasing wear. Worming, parceling, and serving, done in the order given, increase rope wear. (See Fig. 7–11.) Before any of these is done, the rope must be so arranged that at all times it is held taut, preferably in a horizontal position, at a convenient height for working. The rope must be clean and in good condition.

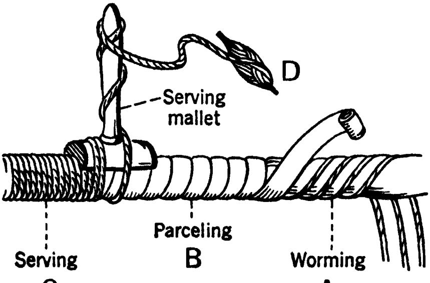


FIG. 7–11. Worming, parceling, and serving.

Worming consists of winding a small cord tightly around the rope, following the divisions between the strands. (See Fig. 7–11*A*.) This gives the rope a smooth, even, round appearance. Naturally, the direction of winding should be with the lay.

Parceling takes place after worming. This consists of winding evenly and tightly a narrow strip of tarred canvas, with overlapping edges, around the outside of the wormed rope, in a direction with the lay. (See Fig. 7–11*B*.) It is similar to the way electrician's tape is wound on the holding end of a baseball bat or on the handle of a screwdriver.

Serving is the last step. This consists of winding a small cord tightly, closely, and evenly around the outside of the rope, on top of the canvas parceling, in a direction against the lay. (See Fig. 7–11*C*.) The most important feature of good serving is tightness. It can be readily understood that if the cord is wound loosely around the rope, it will slip and become uneven, exposing parts of the rope to wear, and gather in clumps that may prevent the rope from readily passing over the sheaves of pulleys. To make sure of tightness, a serving mallet is used. Figure 7–11*D* shows a serving mallet in use. Note that there are several turns of cord around the handle and several around the curved mallet resting on the rope. Grasping the handle and the rope wound around it gives powerful leverage for making each turn of the serving very tight.

Worming, parceling, and serving aid greatly in protecting rope against dampness and the weather, and prevent rope from being weakened by chafing (friction or rubbing).

C. SPLICES

Splicing is another means of avoiding rope waste and, in addition, it is one of the ways of putting rope to work. In general, *splicing* is the joining by interweaving of (1) two separate pieces of rope or (2) the end of a rope to the main body.

1. SERVING SPLICE

Serving splice, or *whipping*, consists of tightly and closely winding a small cord, twine, or fishline around the end of a rope to prevent it from unraveling and fraying. It is similar to the method of serving that we already considered. There are several different ways of making a serving splice, but only one that is commonly used is considered here. The steps in making it are listed below and shown in Figure 7–12.

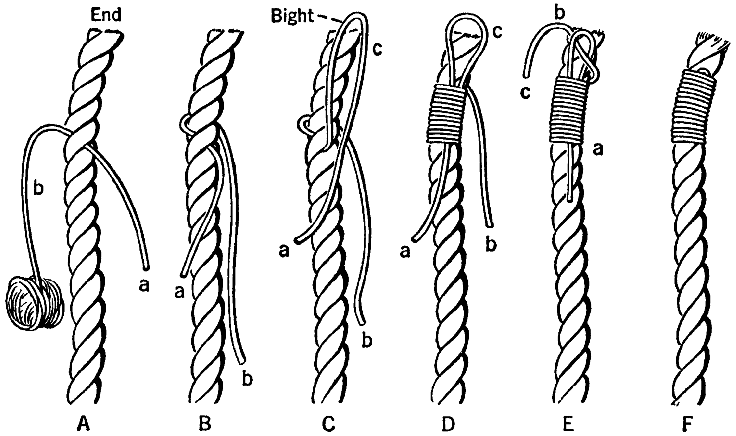


FIG. 7-12. Steps in making a serving splice.

(1) If the strands are separated, replace them in their normal lay.

(2) If the whipping is to be short, unravel *one* strand to the point where it is to begin. Slip the whipping cord under this strand, as in Figure 7–12*A*, and relay the strand. If the whipping is to cover a rather long stretch of rope, hold the rope in both hands at the point where the splice is to begin. Turn your hands in opposite directions, twisting the rope against the lay. In the space between the two hands the strands will part, permitting the cord to be inserted. As soon as the pressure of twisting is released, the strands will fall back into their normal lay, although twisting a little with the lay will help.

Another method is to insert a marlinespike or a fid between two strands to separate them. A *marlinespike* is a round steel tool, 12 inches long and about 1 inch in diameter, tapering to a point. The butt (thick) end is rounded off and contains a quarter-inch hole drilled through; in other words, it is much like a giant-size needle. A *fid* is similar to a marlinespike but larger, being up to 2 inches in diameter at the butt end and more than a foot in length. Further, it is always made of a very hard wood such as lignum vitae, hickory, or oak and is finished smooth and polished. The taper of the marlinespike or fid can be from end to end or it may begin at any point near the thick end that will make a long, gradual taper.

(3) Arrange the whipping cord so that a shorter piece *a* sticks out and the longer part *b* is left behind, as in Figure 7–12*A*. Because of its use, as will be explained later, the short piece *a* should be much more than twice the distance to be whipped. The long piece *b* may be of any length and therefore need not be cut off from the ball of whipping cord until very near the end of the process.

(4) Hold the rope with the end up or away from the body. Let the short piece *a* of the whipping cord hang. Just at the point where it comes out from under the strand, wind the longer piece once tightly and completely around the rope, as in Figure 7–12*B*.

(5) Fold the short piece and place it so that the bend *c*, or *bight*, which is its proper name, is at the end of the rope. Arrange the doubled cord flat in the groove between two strands, as in Figure 7–12*C*. This groove is properly called the *contline*.

(6) Hold the bight in place with the thumb and wind the long part over the doubled cord and rope tightly, and at right angles to the length of the rope, as in Figure 7–12*D*, up to about a quarter-inch from the end of the rope.

(7) Cut the cord from its roll, leaving an extra few inches. For the last winding, pass the end of the cord through the bight, as in Figure 7–12*E*.

(8) Pull the short end, which is sticking out from the whipping, where it was begun. This will make the bight at the other end smaller. Further pull on the short end will draw the long end under the whipping.

(9) Cut off the protruding part of the short and long ends flush with the whipping, as in Figure 7–12*F*.

Whipping is useful not only to bind together frayed ends of a rope, but also to provide a good grasping surface on commonly used tools, such as tennis rackets, fishing poles, and screwdrivers. Remember at all times to keep the strands of the rope tight and to wind the cord close without overlapping the winds.

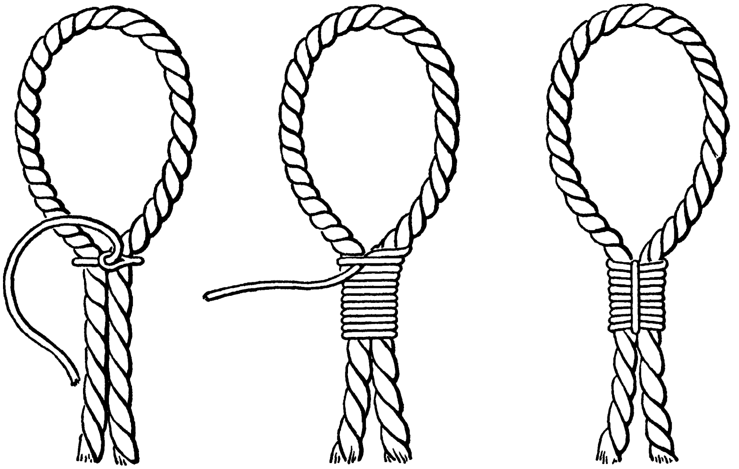


FIG. 7–13. Plain or round seizing.

At times it is necessary to bind two ropes lying next to each other; to make a loop or eye in the middle or end of a rope; to attach a rope to a pole; and other similar needs. *Seizing*, which is similar to whipping, is often used for such purposes. Seizing is explained diagrammatically in Figures 7–13 and 7–14. It is really a small *lashing*, which will be studied later.

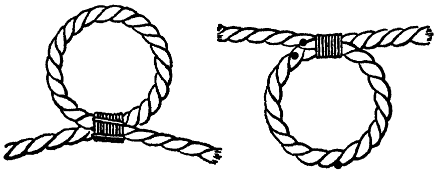


FIG. 7–14. Throat seizings.

2. CROWN SPLICE

A rope end can be prevented from unlaying by use of a *crown splice* (knot) instead of whipping. Sometimes it is called a *back* *splice.* It is a convenient substitute to use when there is no small stuff or cording at hand or where it is desired to have a decorative end to the rope. The steps are listed below and shown in Figure 7–15.

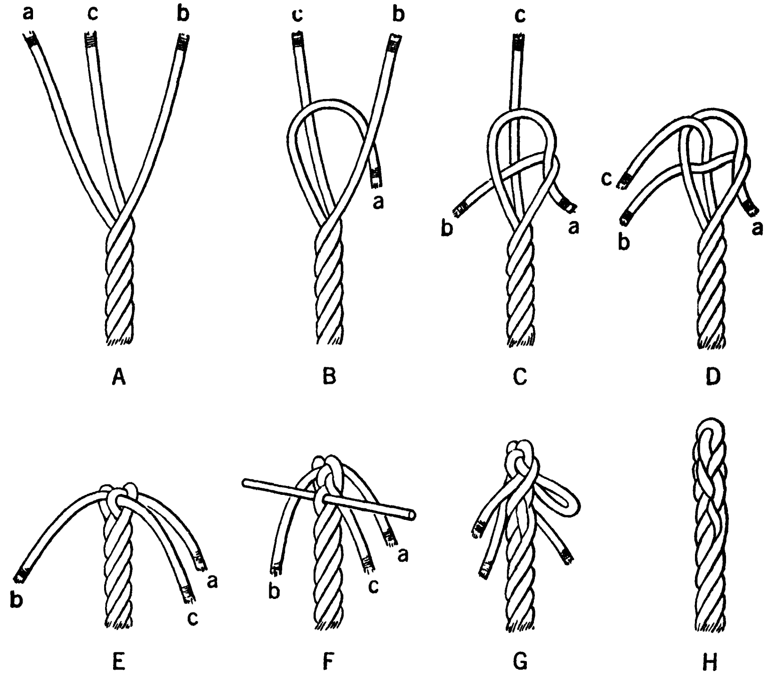


FIG. 7-15. Steps in making a crown splice or knot.

(1) Unlay the rope (that is, untwist and separate the strands) for about one foot. Hold the rope in one hand with the strands up, as in Figure 7–15*A*.

(2) Make a bight in one strand *a*. Place the free end between the two other strands, leaving the bight loose as shown in Figure 7–15*B*.

(3) Make a bight in another strand *b*. Place it so that the free end of strand *a* is inside and its own free end lies between the first bight and the third strand *c* as in Figure 7–15*C*.

(4) Make a bight in the strand *c*. Run its free end through the bight of strand *a* and over the free end of strand *b*, as shown in Figure 7 15*D*.

(5) Pull tight the free ends of the three strands, as in Figure 7–15*E*. These free ends can be tucked, as shown in Figures 7–15*F*, *G*, and *H*. The steps in tucking will be explained later.

(6) Roll the splice under pressure between the foot and the floor to smooth and even it.

Thus the crown splice is a sort of braiding where each strand acts to hold down the other two.

3. EYE SPLICE

When it is necessary to make a permanent loop or eye at the end of a rope, the eye splice is used. The length of the rope required is one and one-half times the circumference of the eye. It is about 90 per cent as strong as the rest of the rope. A metal oval, called a *thimble*, usually is placed inside the eye or loop when it must stand heavy wear. Figure 7- 16 shows the steps in making an eye splice.

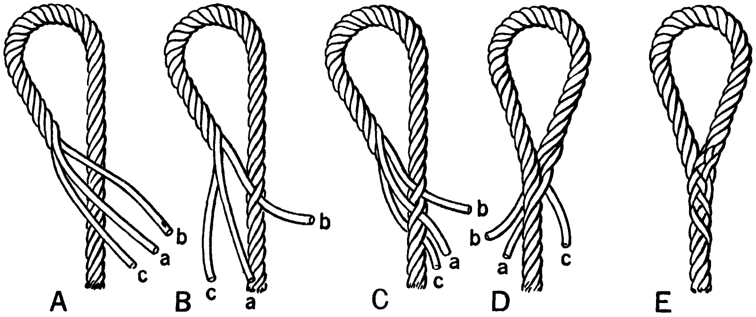


FIG. 7–16. Steps in making an eye splice.

(1) Unlay the strands at the end for 12 to 16 inches.

(2) Make a bight of sufficient size to make the eye as shown in Figure 7–16*A*. Note that the size of the eye depends on the

distance from the point where the strands are unlaid to the point on the body of the rope mentioned in step (3).

(3) Place the unlaid strands on top of the body of the rope, as in Figure 7–16*A*. At the proper distance to form the eye, raise the topmost strand of the body of the rope as in Figure 7–16*B*.

(4) Select the topmost free strand, *b*, and tuck it under the strand raised in step (3) at right angles to the rope. Pull it tight.

(5) Raise an adjoining strand on the rope body and tuck the nearest free strand, *a*, under it at right angles. If done properly, this second free strand will not cross either of the other two. Pull it tight. (See Fig. 7–16*C*.)

(6) Raise the third strand on the body of the rope and tuck the last free strand *c* under it, as in steps (4) and (5). Again note that this free strand should not cross the other two. Pull it tight. (See Fig. 7-16*D*.)

(7) Interweave the strands as for the short splice, as shown in Figure 7–16*E*.

(8) Roll the splice under pressure between the foot and the floor. Cut off the free ends of the strand almost flush with the body of the rope.

4. SHORT STRAIGHT SPLICE

This is one of the commonly used methods for joining two pieces of rope. It is easy to make, but it has only about 8 per cent of the strength of the rest of the rope. Its chief disadvantage is that through the length of the splice the rope is twice as thick as the unspliced parts. This makes the spliced rope useless for a pulley or block and tackle, for its extra thickness prevents the rope from passing through. The steps for making a short straight splice are given below and shown in Figure 7–17.

(1) Unlay the strands for about a foot or a foot and a half, according to the size of the rope. Spread out the strands, as shown in Figure 7–17*A*.

(2) Place the unwound part of one rope snugly against the un-

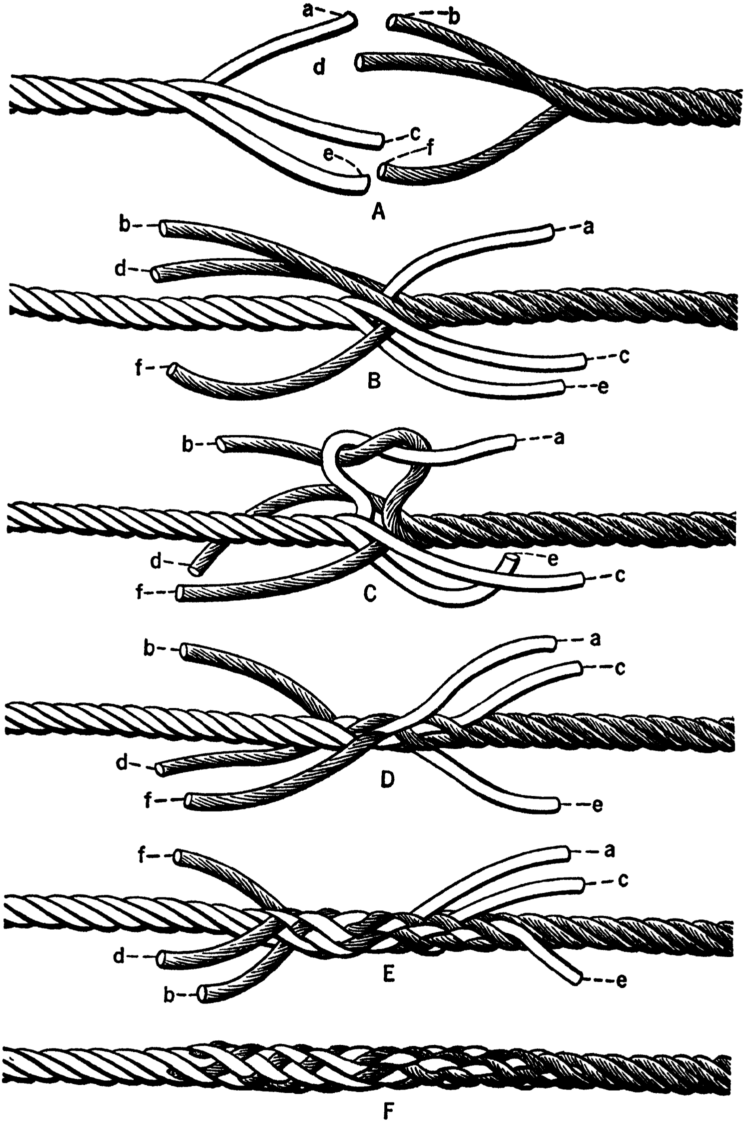


Fig. 7-17. Steps in making a short straight splice.

wound part of the other to *butt* them. Arrange the strands so that they alternate; that is, one strand of one rope follows one strand of the other rope. This is termed *locking the strands.* In this way no two strands of one rope will be next to each other. Temporarily tie the two ropes together in this position. (See Fig. 7–17*B*.)

(3) With a single overhand knot, tie together two strands lying next to each other. (See Fig. 7–17*C*.) Make sure that the twist of the rope is followed. Do this with the remaining two sets of strands, pulling each knot tight before the other is begun. (See Fig. 7–17*D*.) (Sometimes, however, this step is omitted.) Remove the temporary holding twine of step (2).

If the correct knots were made and the ropes were held closely together, it will be found that the free ends of one rope lie over the other rope almost at right angles with the twist of the ropes. This must be followed by *tucking,* steps 4, 5, 6, and 7.

(4) Take the end of one free strand. Skip the rope strand nearest it. Slip the free strand under and out from the second rope strand. In other words, do not tuck it under the adjacent strand but under the second one from the free strand. Be sure to keep the free end of the strand at right angles with the rope twist; that is, keep it running in the same direction as the length of the rope. Use a fid or marlinespike to lift the rope strand. (See Figs. 7–15*F* and *G*, and 7–17*E*.)

(5) Do the same with the remaining free strands.

(6) After each strand has been tucked once, the operation is repeated until the total length of tucking is 4 inches for a quarter-inch rope. Add an extra tuck for each larger size rope. Remember to tuck under the second strand, not under the one next to the free strand. (See Fig. 7–17*F*.)

(7) As with the crown splice, roll the short splice under pressure between the foot and the floor to smooth and even it out. Cut off the strand almost flush with the rope.

Tapered tucking. Originally the free strands were twisted. This adds to the bulkiness and thickness of the splice. If, however, the end of each tucked strand is given a sharp twist in the opposite direction before it is pulled tight, it will flatten out the fibers and yarns and reduce this bulkiness.

Before the last two or three tucks are made, cut off about a third of the fibers of the free strand. This will gradually thin it out and finally provide a neatly tapered splice, as shown in Figure 7–18. Cut off the ends that are still left, but not too close to the rope itself.

5. LONG STRAIGHT SPLICE

The long straight splice is much better than the short straight splice. It leaves the rope almost the same width as before splicing. This makes it possible to use the spliced rope in pulley work. Further, it is about 90 per cent as strong as the rope itself, and it is much stronger than the short splice. The steps in making this splice are given below and shown in Figure 7–18.

(1) Unlay only *one* strand of each rope for about 12 turns. Butt together the two ropes at the point where the unwinding of the strands stops. Arrange them so that the two loose strands are side by side as shown in Figure 7–18*A*. Note that each of these two strands runs in the direction of the other rope.

(2) Take care that the ropes do not separate. Unlay strand *a* of the right rope for one turn. Lay strand *b* of the left rope in the lay of the right rope just where it was unwound once. Be sure to keep this strand tight in its new lay. If it does not lie naturally in the new lay, twist it until it does. (See Fig. 7–18*B*.)

(3) Repeat step 2 to the right until only 6 to 9 inches of the left-rope strand *b* are left. Naturally, the number of times this step must be repeated will depend on the size of the rope.

(4) Go back to the point where this unlaying and relaying was begun in step 2. This is the point where the ropes butt against each other. Unlay the two remaining strands of each rope. Lock them. (See step 2 of the short straight splice.) If this is done properly, it will be found that the strands are in the following order. The first strand to the left, *d*, comes from the left rope. The second strand *c* comes from the right rope. The third strand *f*

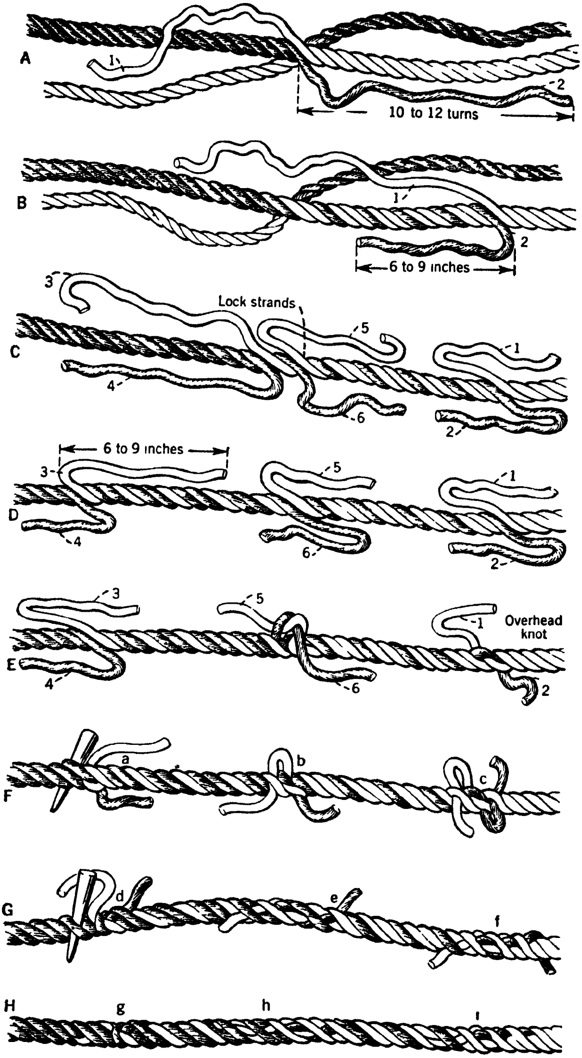


Fig. 7–18. Steps in making a long straight splice.

is from the left rope. The fourth strand *e*, the one farthest to the right, is from the right rope. (See Fig. 7–18*C*.)

(5) Unlay one turn of strand *d*, the first one on the left and belonging to the left rope. In its lay, wind strand *c*, which is the next one and belongs to the right rope. Repeat this process as explained in steps 2 and 3, until strand *c* is about 6 to 9 inches long. (See Fig. 7–18*E*.)

(6) Cut all strands to the length of the shortest, 6 to 9 inches long. Arrange each pair so that the strand from the left rope is in front of the strand from the right. In this position they cannot unwind from the rope without first uncrossing.

(7) Tie together each pair of strands with an overhand knot as was done in step 3 of the short splice. (See Fig. 7–18*E*.)

(8) Tuck each strand once as in step 4 of the short splice. (See Fig. 7–18*F*.)

(9) Taper as previously explained. (See Fig. 7–18*G*.)

(10) Pound down each part of the splice with a round stick. Roll the entire splice under pressure between the foot and the floor to even and smooth it out. (See Fig. 7–18*H*.)

6. CUT SPLICE

When two ropes are to be joined in such a fashion that a loop or eye is made at the place of joining, the cut splice is used. (See Fig. 7–19.)

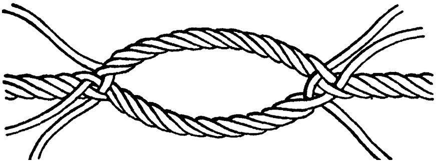


FIG. 7–19. A cut splice.

(1) Unlay the ends of the rope for a distance depending on the size of the rope, as for an eye splice.

(2) At a suitable distance on one rope, which distance will be half the total circumference of the eye, splice the other rope as for an eye splice.

(3) Do the same on the other rope.

(4) Even and smooth out the splice as for an eye splice.

D. KNOTS AND THEIR USES

Knotting is generally a misunderstood skill, usually associated only with the work of sailors. Actually a knowledge of knotting is important in many activities of man, such as the operation of derricks, hoists, and cranes used in large construction projects; in the shipping room for tying packages; on trucks and freight cars to prevent merchandise from slipping; in emergencies for rope bridges and rescue slings; and so on.

There are thousands of different kinds of knots, each with its own specialized use. There are few people who are masters of the entire field of knotting, for to master all the kinds of knots would be a life's work.

Classification of knots. The United States Naval Institute divides all knots into four large classes as follows:

(1) Knots in the end of a rope, for fastening a line upon itself or around some other object, as the *bowline*, *bowline on a bight*, *cat's-paw*, and *figure 8*.

(2) Knots for *bending* (binding, joining, securing, tying) two ropes together, as the *square knot*, *single sheet* or *becket bend*, and *two bowlines*.

(3) Knots, called *hitches* and *bends*, for securing a line to a ring or spar (a heavy, round timber, as a mast of a ship or part of a derrick or crane), as the *clove hitch* and *snubbing hitch*.

(4) Knots on the end of a rope to finish off the rope and to prevent it from unraveling or fraying and to prevent it from pulling through a ring or pulley, as the *crown knot* and *serving splice*.

Learning knotting. In the following explanations for making various knots, the instructions have been broken up into simple steps. In addition, as for splices, there are step-by-step diagrams showing how the rope is handled to form the particular knot. Only the simple common knots are discussed here. You should not have much difficulty learning them if you study the text and diagrams carefully.

The best way to learn is by *doing.* With a little concentration and practice you can easily learn these simple knots. Obtain a three-strand rope, say half-an-inch in diameter, and go to work.

It is easy to know when you have mastered the art of tying each knot. When you can tie a knot in a pitch-dark room, or with the hands hidden under a table, or with your eyes closed, you have mastered that particular knot and you will not easily forget it. Remember, you may sometime need this knowledge in an emergency at night when a light may not be struck, to tie up a boat, to rope logs together for a raft, or to tie up horses until morning.

The overhand or thumb knot. This knot is the simplest of all the knots. It is made by passing the end through an underhand or overhand loop, as shown in Figure 7–20. Its chief use is at the end of a rope to prevent it from slipping through any small opening, as on the wooden seat of a swing.

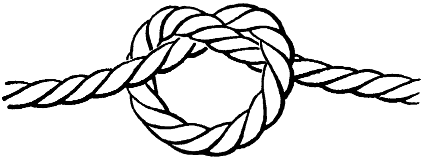


FIG. 7-20. An overhand knot.

1. FIGURE-EIGHT KNOT

This knot is so called because it looks like the number 8. It is most often used at the end of the fall line to prevent its slipping

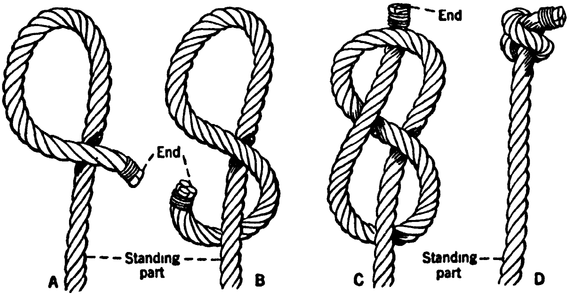


FIG. 7–21. Steps in making a figure-8 knot.

through a pulley. It can also be used to provide a grip on a rope. The steps in making it are shown in Figure 7–21 and listed below:

(1) Make an underhand loop, as in Figure 7–21*A*.

(2) Bring the free end under and around the standing part, as in Figure 7–21*B*.

(3) Continue the free end over the left side of the loop, through the loop, and under the loop, as in Figure 7–21*C*.

(4) Pull tight as in Figure 7–21*D*.

2. BLOCK-BECKET BEND

The block-becket bend, which is also known as a single-sheet bend, is used to attach a rope in the form of a loop to the eye of a guy rod or to the becket of a pulley. The *becket* is the immovable part at the bottom of a pulley to which is attached one end of a rope. The steps in making this knot are shown in Figure 7–22.

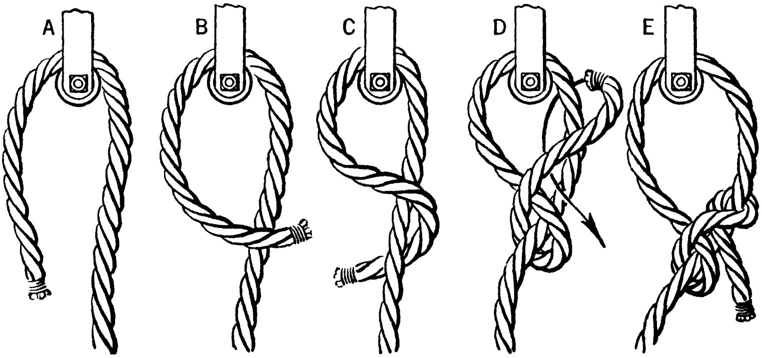


FIG. 7–22. Steps in making a block-becket bend.

(1) Pass the end of the rope through the becket or eye, as in Figure 7–22*A*.

(2) Form a loop, as in Figure 7–22*B*.

(3) Bring the end once around the standing part, as in Figure 7–22*C*.

(4) Pass the end under the right side of the loop, through it, and between the end and the loop, as shown in Figure 7–22*D*.

(5) Pull it tight as in Figure 7–22*E*.

3. SQUARE KNOT

This knot is used when two ropes of the *same* size are to be united and they will have to stand a strain. It is the most commonly used knot for joining two pieces of rope. If the ropes are of unequal sizes, the square knot should not be used, because in that case there is a tendency for the ropes to slip apart. The single-end bowline should be used. The steps for making the square knot are shown in Figure 7–23 and listed below:

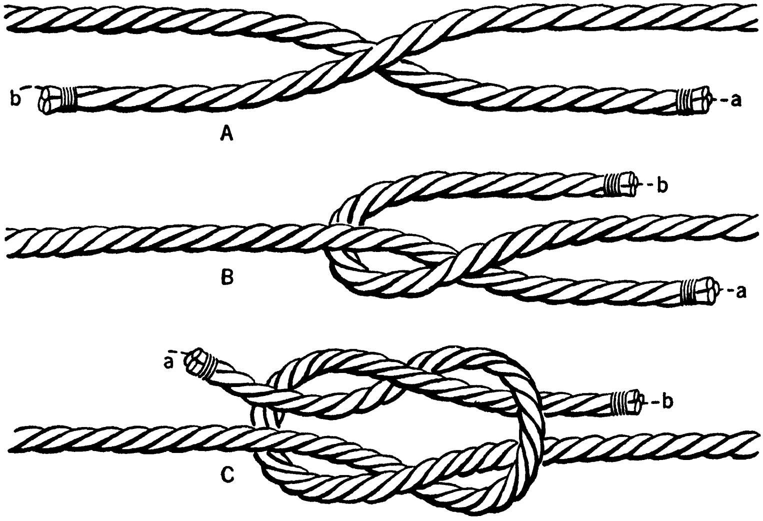


FIG. 7–23. Steps in making a square knot.

(1) Cross the ropes over each other, as shown in Figure 7–23*A*, keeping the right rope over the left rope.

(2) Make a bight in the right rope, *b*, as shown in Figure 7–23*B*.

(3) Wrap the end of the left rope, *a*, over and then under the end of the right rope, *b*, pulling it through the bight of the right rope so that finally this left end lies parallel to the left rope, as in Figure 7–23*C*.

(4) Pull all parts tight.

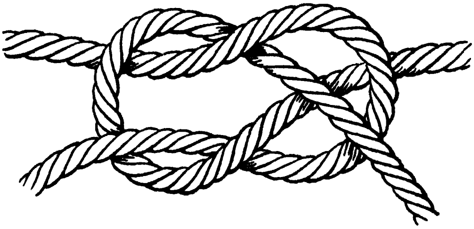


FIG. 7–24. A granny knot.

Be careful *not* to make a *granny knot* which is shown in Figure 7–24. Note that the square knot is merely two bights braided into each other. The granny knot, on the other hand, has the ends of the ropes separated by the bight.

4. BOWLINE KNOTS

There are several dozen different kinds of bowline knots. Of these we shall consider only the five most useful types. Bowline knots are one of the best means for attaching ropes so that they will hold fast under strain but, when necessary, can easily be freed (hitches). Successful bowline knots, then, are easily tied and untied.

Single-end bowline, end free. This knot is used for attaching a rope to the hook of a block or for tying together the ends of ropes of *different* sizes. The steps in making this knot are shown in Figure 7–25, and listed below:

(1) At the proper distance from the end of the rope, make an underhand loop, as shown in Figure 7–25*A*.

(2) Pass the end through the loop as if an overhand knot were being made. (See Fig. 7–25*B*.)

(3) Bring the end around and behind the standing part from right to left, and down through the loop from above, as in Figures 7–25*C*, *D*, and *E*.

(4) Pull all parts tight.

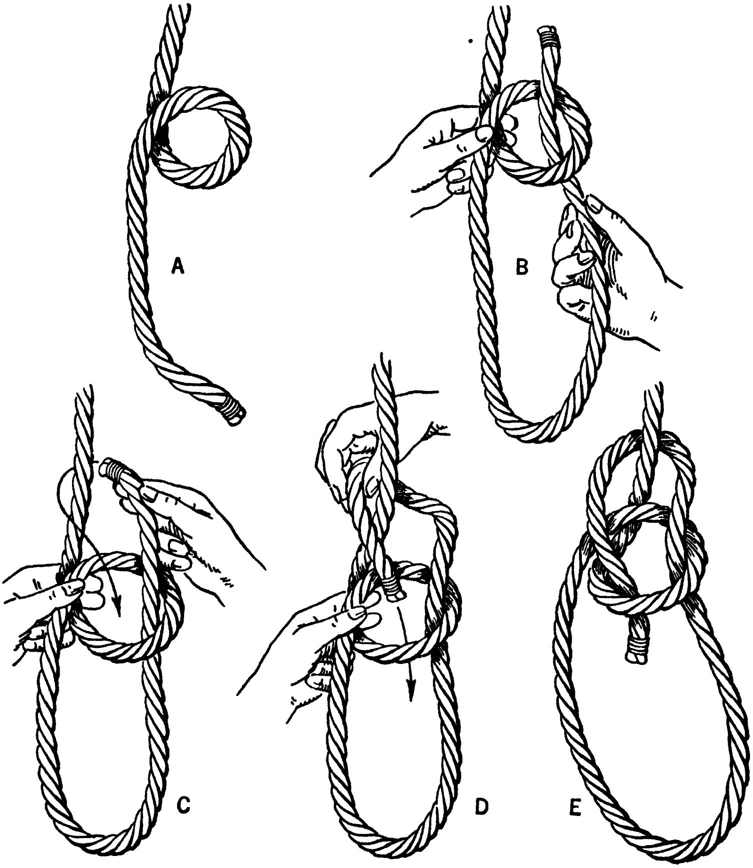


FIG. 7–25. Steps in making a single bowline at the end of a rope not attached to an object.

Single intermediate bowline, end attached. When the end of a rope cannot be used but the rope must be attached to the hook of a block, the single intermediate bowline is used. The steps in making this knot are exactly the same as for the single bowline, free end, except for step (2). Since there is no free end, a bight is made in the rope at a suitable distance. This bight is used as if it were a free end in the single bowline knot already described. (See Fig. 7–26.)

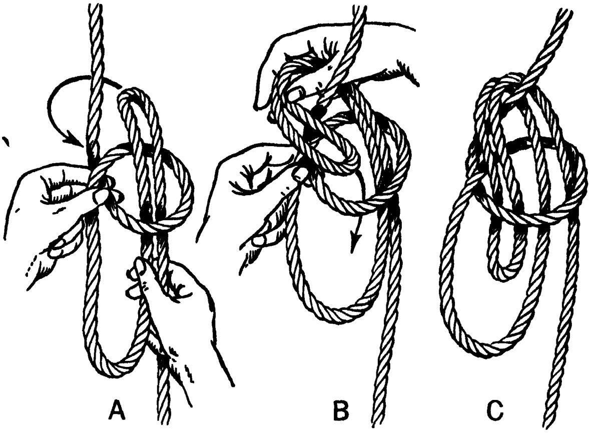


FIG. 7–26. Single intermediate bowline, end attached.

Single-end bowline attached. This knot is used for tying through a ring or eye. The steps are shown in Figure 7–27 and listed below:

(1) From the left pass the end of the rope through the eye or around the object, as shown in Figure 7–27*A*, making a bight.

(2) In the standing part which is in the left hand, make an overhand loop. (See Fig. 7–27*B*.)

(3) Bring the end through the loop, as in Figure 7–27*C*.

(4) Bring the end over the standing part and around to the left, then pass it through the loop from the rear. (See Fig. 7–27*D*.)

(5) Pull the parts tight, as shown in Figure 7–27*E*.

Double bowline knot. This knot makes it possible to have two ropes pass through an eye or around an object which doubles the strength of the rope at the point of greatest stress or pull. It is made exactly like the single-end bowline knot just explained, except for step (1). Instead of passing a single rope through the eye or around the object, the rope is first doubled for the proper length needed to make the knot. Then the doubled rope, bight

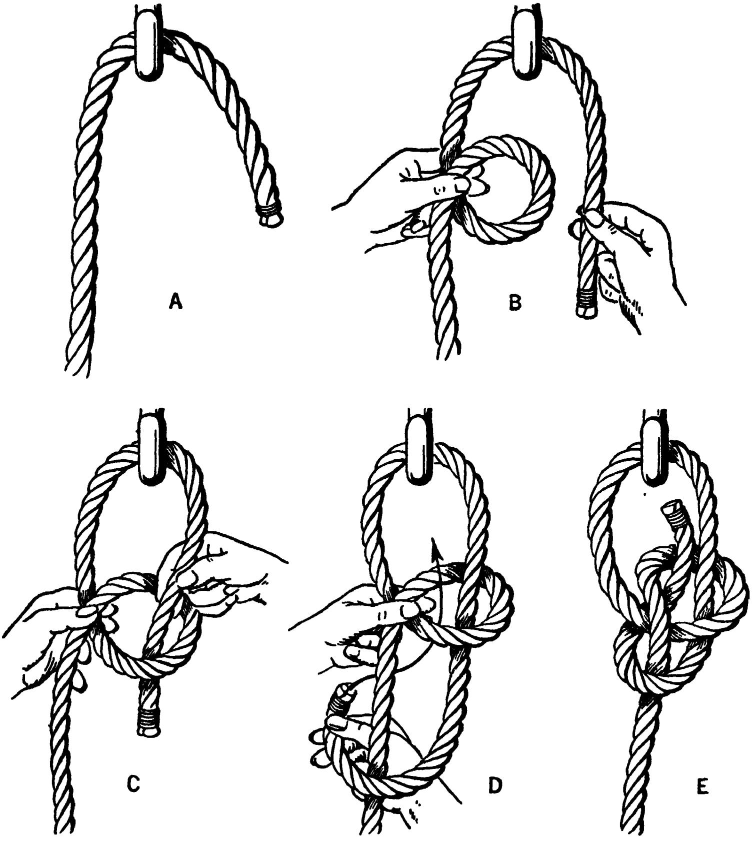


FIG. 7–27. Steps in making a single-end bowline attached.

part first, is passed through the eye or around the object. Then all the steps in making the single intermediate bowline knot are followed. (See Fig. 7–28.)

Double bowline on a bight. When it is necessary to have two ropes at the point of greatest stress, as a semipermanent eye in the middle or end of a rope to engage a hook or other similar attachment, the double bowline on a bight is used. It increases

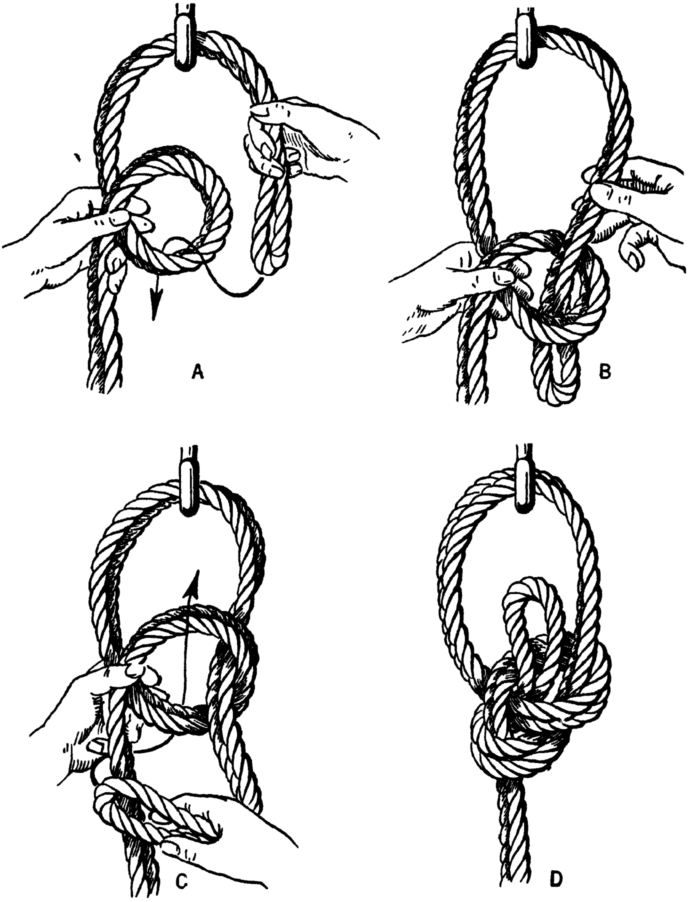


FIG. 7–28. Double bowline knot.

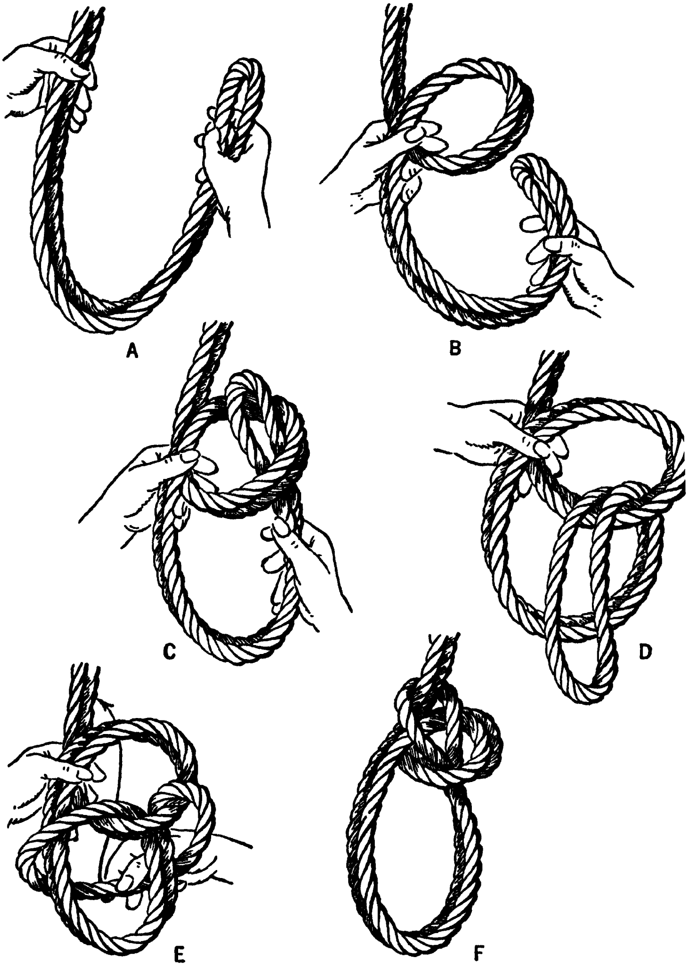


FIG. 7–29. Steps in making a double bowline on a bight.

the strength of the rope, and can be used without disturbing the rope ends. The steps in making this knot are shown in Figure 7–29 and listed below.

(1) By making a bight, double the rope for a length sufficient to make the knot, as in Figure 7–29*A*.

(2) At the proper distance from the bight, make an underhand loop, as in Figure 7–29*B*.

(3) Pass the end (which contains the bight) under and through the loop from the rear, as in Figure 7–29*C*.

(4) Bring down the bight, as in Figure 7–29*D*.

(5) Open the bight wider and slip it under and around the standing part and bight, as in Figure 7–29*E*.

(6) Continue bringing up the bight until it rests just above the loop, as in Figure 7–29*F*.

5. CLOVE HITCH

The clove-hitch knot is used for tying tools and materials to a line so that they can be lifted or lowered. It is also used for holding poles in place by a tension put on them in several directions, as with tent poles. The clove hitch can be made at the end of a rope or at any intermediate part without using the ends. Actually it merely consists of two jammed half-hitches. The end may be lashed down or seized to the standing part to prevent slipping. There are a number of ways of making the clove hitch, three of which are explained below.

Clove hitch #1. The steps in making a clove hitch to pass *over* low objects, such as a short pole or stake, are shown in Figure 7–30 and listed below.

(1) Make a loop, as shown in Figure 7–30*A*.

(2) If the loop in step (1) was underhand, make another loop to the left that is overhand, as in Figure 7–30*B* or vice versa.

(3) Place the right loop over the left loop, as in Figure 7–30*C*.

(4) Place both over the object, as in Figure 7–30*D*.

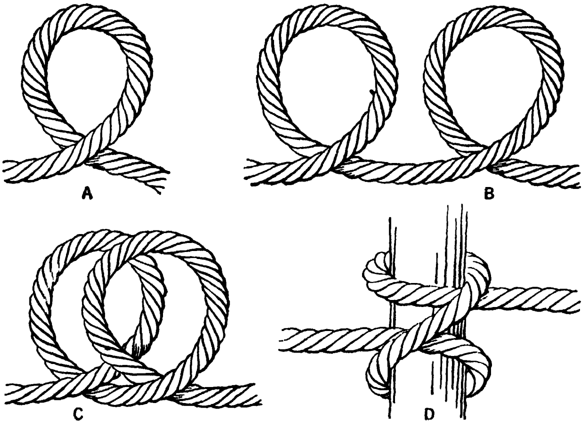


FIG. 7–30. Steps in making clove hitch #1.

Clove hitch #2. When there is a strain or pull on the rope, the clove hitch is made according to the steps shown in Figure 7–31 and listed below.

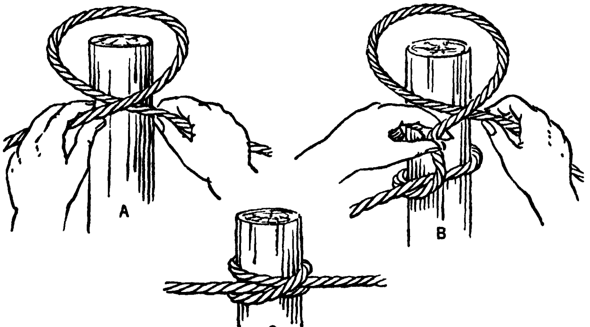


FIG. 7–31. Steps in making clove hitch #2.

(1) Hold the strained rope with the left hand, as in Figure 7–31*A*. The unstrained or loose part will be on the right.

(2) Make a loop on the loose part, as in Figure 7–31*A*.

(3) Place the loop over the object, as in Figure 7–31*B*.

(4) Hold the right part with the left hand and make another loop with the right hand. Note that if the first loop was underhand the second one should be overhand, and vice versa.

(5) Pull taut.

Clove hitch #3. The quickest way of making a clove hitch is shown in Figure 7–32.

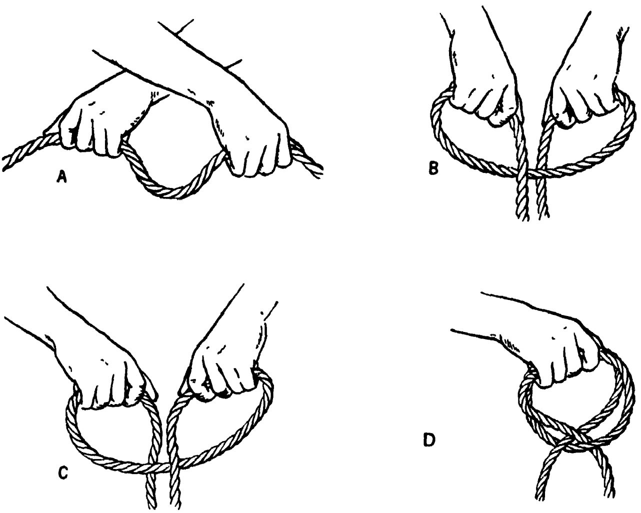


Fig. 7-32. Steps in making clove hitch #3.

(1) Place the rope down on the ground stretched out.

(2) Cross the arms so that the left arm is outside the right. Pick up the rope as in Figure 7–32*A*.

(3) Uncross the arms without twisting the wrists, as in Figure 7–32*B*.

(4) Rotate both wrists to the right, as in Figure 7–32*C*, and place the knuckles of the left hand in the palm of the right hand.

(5) Move the two loops that were thus formed from the left hand into the right hand, as in Figure 7–32*D*.

(6) Place the clove hitch over the object.

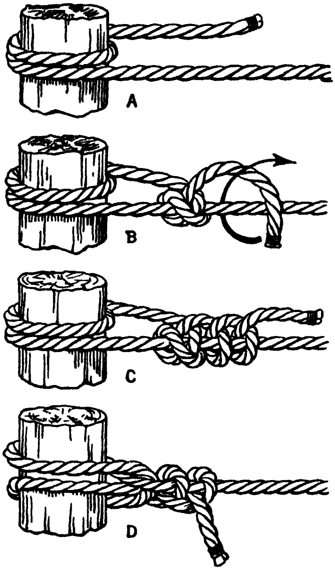


FIG. 7–33. Steps in making a snubbing hitch.

6. SNUBBING HITCH

This knot is used when guy ropes must be attached to a pole to brace or steady it. The steps in making it are shown in Figure 7–33 and listed below.

(1) Wind the rope twice around the object, as in Figure 7–33*A*.

(2) Bring the end over the standing part, then under it and through the loop, as in Figure 7–33*B*.

(3) Bring the end forward and down again across the standing part. Pass the end upward again through the loop. (See Fig. 7–33*C*.)

(4) Complete with two half-hitches as in Figure 7–33*D*.

(5) Pull taut.

7. CAT'S-PAW

The cat's-paw knot is used when it is necessary to attach a rope to the hook of a block. It allows a double rope to be placed over the hook and permits a load to be carried on either end of the rope. The steps in making it are shown in Figure 7–34 and listed below.

(1) Pick up the rope with both hands, palms held inward, as in Figure 7–34*A*.

(2) Move the hands together to form a bight in the rope. Then turn the hands, palms outward, to form two loops, as in Figure 7–34*B*.

(3) Make another half-turn in the same direction as in step (2). (See Fig. 7–34*C*.)

(4) Repeat step (3) and place the end of both loops over the hook, as in Figure 7–34*D*.

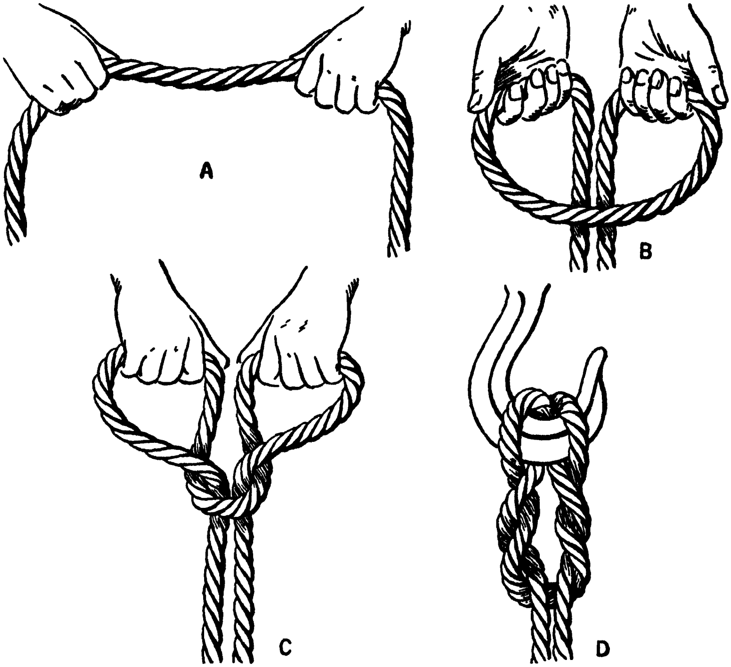


FIG. 7–34. Steps in making a cat's-paw.

8. PLATFORM GUY KNOT

A guy rope is one used for steadying or bracing objects. Wiremen working high up on a pole usually sit or stand on a platform. The knot used to secure the guy ropes from such a platform to a pole or ladder or other support is the platform guy knot. The steps in making it are shown in Figure 7–35 and listed below.

(1) Pass the rope once around the pole so that the end comes back over the standing part, as in Figure 7–35*A*. Pull to the desired tension.

(2) Pass the rope down and under the standing part and bring it around the pole above the first turn in a direction oppo-

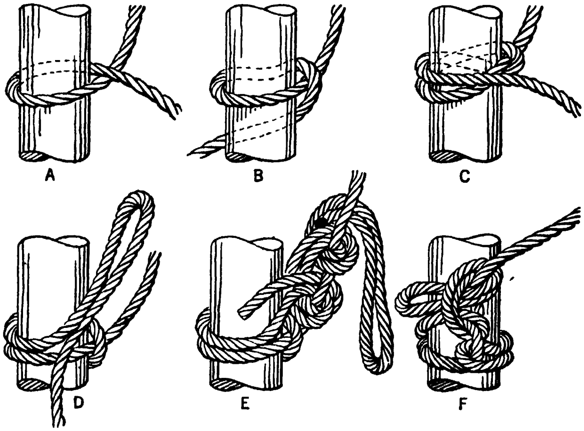


FIG. 7–35. Steps in making a platform guy knot.

site to that in step (1). (See Fig. 7–35*B*.) Pull to the desired tension.

(3) Secure the end to the standing part with two half hitches, as in Figure 7–35*E*. If the end is too long, it should be doubled before this step is followed. (See Fig. 7–35*D*.)

(4) Pull tight as in Figure 7–35*F*.

9. LASHINGS

Lashings are used when things such as poles or spars must be attached temporarily. Reference to lashings was made when we considered seizing. The type of lashing to be used depends on (*a*) ease of attaching, (*b*) ease of detaching, and (*c*) safety factor. Only good rope should be used. The size should be that shown in the table on page 395.

A lashing when the pull is at right angles with the pole is shown in Figure 7–36*A*.

A lashing when the pull is parallel to the pole is shown in Figure 7–36*B*. Note that the number of turns around the pole should always equal the number through the hook.

ROPE SIZE FOR LASHINGS

Size of block	Number of turns required through block hook depends on size of rope as shown:				
	3/8″	1/2″	5/8″	3/4″	1″
3 inch; 1 sheave	2				
3 inch; 2 sheaves	3	2			
3 inch; 3 sheaves	4	3			
4 inch; 3 sheaves		4	3	3	
6 inch; 3 sheaves			4	4	3
8 inch; 3 sheaves					4
6 inch; snatch			4	4	3
8 inch; snatch					4

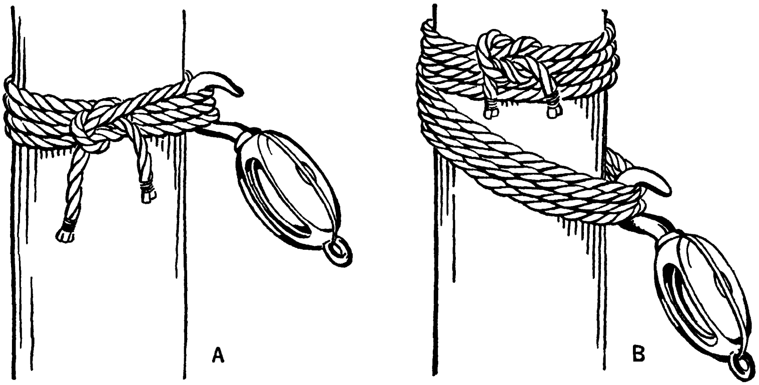


FIG. 7–36. Two types of lashings.

E. BLOCKS

A squad of American soldiers was suddenly confronted with the serious problem of moving men and supplies to the top of a precipice. Its side was so steep that to climb it and carry the supplies to the top was out of the question. The squad leader noticed a tree growing near the top edge of the precipice and without hesitation he called for a coil of rope. Weighting the end with a small rock, he skillfully tossed the rope upwards. After several trials, he finally got it around the tree. The weight of the rock pulled the free end down.

Immediately one of the soldiers tied the weighted end around himself. With his fellow soldiers pulling on the other end and with a little leg work, he was soon on top of the precipice. He freed himself from the rope and lowered it. A machine gun was tied to the rope and hoisted to the top. Soon all the supplies and all the men were on top, entrenched and ready for action.

Naturally, when the operation was completed, the rope was practically useless. The constant rubbing around the tree was not the best way to treat it. If the rope had been pulled through a block, or *pulley*, instead of around a tree, the wear and tear on the rope itself would have been avoided and much needless labor, due to the friction of the rope, would have been prevented.

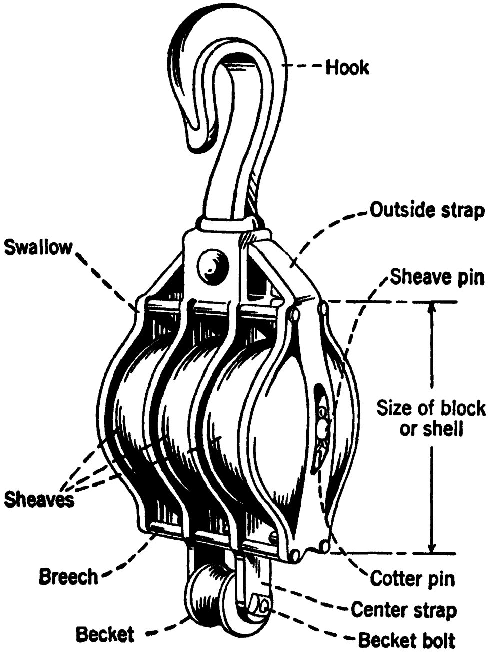


FIG. 7-37. A block.

1. BLOCK PARTS

One or more sheaves (grooved wheels) held in a frame are called a *block*. Figure 7-37 shows one type of block with its various parts indicated. The same names are given to similar parts on other block forms although these blocks may differ somewhat from the one illustrated. By referring to the illustration and the worded descriptions below, you should have very little difficulty in understanding what the block parts are, their location, and their uses.

Shell. This is the frame, usually made of metal, wood, or composition material. Its chief purpose is to hold the shaft on which the pulley spins. It is also the part to which the block hook, shackle, or eye, and the becket are attached.

Sheave. This is the correct name for the grooved wheel on which the rope rolls. It is sometimes called the *pulley.*

Hook. This is the curved or bent piece by which the block is held in place or to which is attached the weight to be moved. The hook is attached to the frame by a strap or bolt and nut. Some blocks have a shackle or eye instead of a hook.

Becket. This is a small wheel on the block on the end opposite to the hook. It is usually attached to the frame by a bolt and nut passing through a strap and the center of the becket wheel. When two blocks are used together, one end of the rope must be attached immovably to one block. The becket is used for this.

Becket bolt. This is the bolt that passes through the becket and attaches the becket to the strap on the block. It serves as a shaft on which the small wheel can move.

Bushing. When a part of a machine moves while supported by another, the softer of these two parts will become worn in time. For example, consider the steering apparatus of an automobile at the place where it is attached to the wheels, or a shaft supported by a bearing. In time the softer part may become worn and lose its fit, causing too much play and unnecessary wobbling. Such a worn part may break and possibly cause a serious accident. Usually a sleeve or liner is inserted snugly in the center opening of the sheave. This is a bushing. It permits accurate adjustment and cheap repair because it is a simple matter to remove a worn-out bushing and replace it with a good one. A well-built block usually has a bushing between the center of the sheave and the sheave pin (shaft) on which it revolves.

Roller bushing. Inspection of the wheels on a good pair of roller skates will reveal a series of small steel balls between the shaft and the hub of the wheel. They serve to reduce friction and the wearing out of parts. Sometimes, as on the wheels of an automobile, instead of ball bearings a series of narrow steel cylinders called *rollers* are used. In a well-built block, roller bushings are usually placed between the hub of the sheave and the sheave pin. Roller bushings in a block should never be oiled.

Cotter pin. This is a type of split pin looking somewhat like the bobby pin used by girls for their hair. Naturally it is made of much stronger steel, does not contain the waves found in a bobby pin, and comes in a variety of sizes. When inserted in a hole, as at the end of a bolt to prevent a loose nut from coming off, the eye end of the cotter pin prevents it from slipping through. When the points at the other end are spread apart, the pin cannot slip off in the other direction. A cotter pin is used to keep the *sheave pin* (the shaft on which the sheaves roll) from slipping out of the block frame.

Center strap. This is a flat strip of steel shaped like a narrow U that sticks out on either end of the block. On the closed end of the strap the hook is attached; the open end supports the becket. The sheave pin passes through the sheaves and center strap.

Outside strap. This is a broad strip of metal that is attached to the sides of the frame and passes over the closed end of the center strap. The eye of the hook not only goes through the closed end of the center strap but also encloses the outside strap. The outside strap thus adds additional support and strength to the hook. In the older type of blocks the strap may be made of rope or wire.

Cheeks. These are the sides of the shell.

Swallow. This is the space between the sheave and the hook end of the block. If the shell is wood, it is grooved at this point to give space to the rope.

Breech. This is similar to the swallow but is located on the becket end of the block.

Thimble. This is a ring sometimes attached to the becket.

2. TERMS WITH REFERENCE TO BLOCKS

Figure 7-38 and the following explanations should make clear some of the various terms employed in working with blocks. Others will be explained as we proceed in the study of the text.

Tackle. This is the arrangement and combination of ropes and blocks used for hoisting or pulling purposes. The rope is called a *fall.*

Running block. This is the block that is attached to the object to be moved, and it moves with the object.

Standing block. This is the block that is attached to a rigid support. Whereas the running block moves with the object, the standing block remains fixed and stationary. The rigid support of a standing block is sometimes called the *anchorage.*

Running end or fall line. This is the free end of the rope in a tackle. It is the part that receives the effort, force, or pull. It is the opposite of the standing end.

Standing end. This is the end of the rope that is fixed or attached immovably to the becket of a block. It is the opposite of the running end or fall line.

Return. This is the part of the rope in the tackle between two blocks.

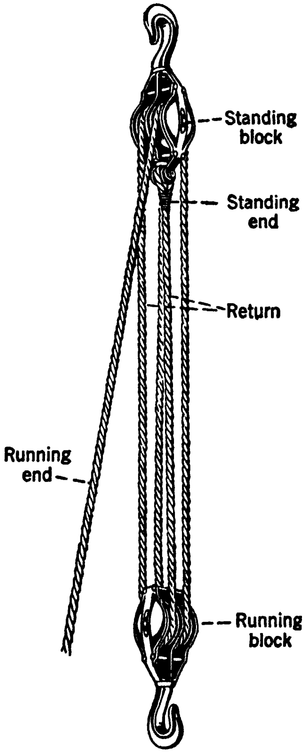


FIG. 7-38. Block terms.

Overhauling blocks. This is done when the running and standing blocks are spread apart, separated, or moved away from each other.

Running-in or rounding-in. This is done when the running and standing blocks are brought close together. It is just the opposite of overhauling blocks.

Chock-a-block. When the blocks of a tackle have been overhauled so much that they touch each other, they are chock-a-block.

Reeving blocks. This consists of passing ropes through the blocks of a tackle so that *mechanical advantage* can be obtained; that is, so that less pulling force is needed than the resisting weight of the object that is to be moved. The past tense of the verb *reeve* is *rove.*

Simple tackle. This consists of one or more blocks rove with a single rope.

The work of blocks. Blocks serve to make work easier and more efficient. For instance they (1) *change the direction of force.* Force may be defined as "pull" or "push." The incident of the soldiers (page 395) illustrates how a block can be used to change the direction of force. The usual arrangement for window weights is another example. Raising a flag by attaching to it a rope which runs through a small block at the top of a pole is still another illustration. In each of these cases it will be noted that a standing or fixed block is used, and that when one end of the rope is pulled in one direction the other end moves in the opposite direction. (See Fig. 7–39.) If one end of the rope is pulled for a distance of one foot, the other end moves one foot. If the object to be moved weighs a pound, then, not considering friction, the force or pull must equal a pound. This arrangement does not increase or decrease the speed of movement. Nor does it afford mechanical advantage, or decrease the amount of force required. The only thing accomplished is a change of direction of the force.

(2) *Blocks reduce force.* One man alone could not lift a piano, but with the proper type and arrangement of blocks, one man could raise a piano to almost any height. Derricks employing similar block arrangements can raise weights so tremendous that no motor alone could budge them. Thus, besides changing the direction of pull, blocks also can reduce the amount of pull necessary, that is, they afford *mechanical advantage.* However, in this case there

is a sacrifice of speed. The rope that is pulled must move through a distance greater than that through which the object itself moves in the same time. This will be explained in more detail later.

3. INSPECTION OF BLOCKS

Always inspect each block before using it. If shell, sheave, or straps are bent, broken, or cracked, or a cotter pin is missing or a roller bushing is not working, discard the block. A bent shell not only is a weak one but it may press against the sheave and require a much greater force of pull than a good one. A cracked or broken shell, sheave, or strap forces the good part to do extra work — its own and that of the damaged part. Such extra stress may make the good part give way too. Also, a damaged sheave may make valuable rope worthless by fraying and cutting it. The cotter pin holds the sheave shaft in place. If it is missing, the shaft may come out, free the sheave, and cause the rope to rub directly on the shell. This is bound to destroy the rope, increase the amount of pull needed, and it may cause an accident. The sheave helps the rope to run through the block easily. A damaged roller bushing may jam the sheave and force the rope to slide on and not roll over the sheave. The resulting friction may soon wear out the rope and it will increase the amount of pull required. Discard immediately a block hook that has begun to straighten. The reasons for this warning have already been explained.

4. STANDARD BLOCKS

We read on page 395 of the problem faced by the soldiers at the foot of the precipice. Their equipment consisted of comparatively light articles. If they had had to get to the top of a sloping hill, they could have moved all their equipment by hand without ropes or blocks. But it was a precipice they faced. What would they have done if their equipment had included a baby tank, a jeep, or a heavy gun? It is clear that they could not hoist this heavy apparatus to the top as they did the lighter equipment, merely by pulling a rope around a tree or even through a block with a single sheave!

We learned that tackle makes it possible (1) to change the direction of force and (2) to reduce the amount of force needed. This, then, would be the solution to the soldiers' problem when needing to lift very heavy objects — use the proper tackle arrangement.

Mechanical advantage of a tackle. There are various possible combinations of blocks and rope to provide mechanical advantage — less force to move a heavy weight. Let us consider two different arrangements. In each the rope is continuous, but in one the standing end is attached to the standing block and in the other the standing end is attached to the running block. In both arrangements the force is applied to the running end or fall line of the rope.

Figures 7–39 and 7–40 show in diagrammatic form the arrangement of rope and blocks in each case. Note that in industry the sheaves in the block roll on the same shaft. However, to simplify and clarify the arrangements, the blocks shown in the illustration have sheaves that roll on different shafts.

Standing block. When the standing end of the rope is attached to the becket of a standing block, the mechanical advantage is always an *equal* number, and the number of ropes supporting the running block is also an *equal* number. This is illustrated in Figure 7–39. Both blocks contain two sheaves each. To move the 4-lb. object, 1 pound of force is needed. Further, to move the 4-lb. object 1 foot, the 1 pound of force must move a distance of 4 feet. The mechanical advantage equals the resistance divided by the force needed to move it. In this arrangement, the *MA* equals 4 divided by 1. The *MA* is 4.

Running block. When the standing end of the rope is attached to the becket of the running block, the mechanical advantage is always an *odd* number, and the number of ropes supporting the running block is also an *odd* number. This is illustrated in Figure 7–40. Note that the standing block has three sheaves and the

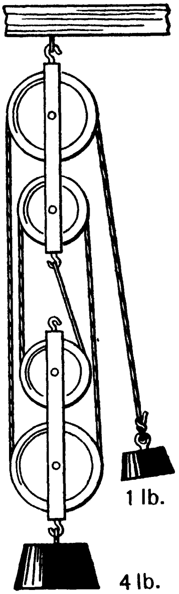


FIG. 7–39. Standing end attached to standing block.

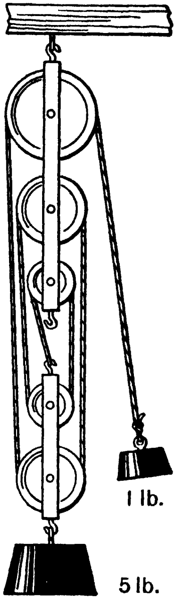


FIG. 7–40. Standing end attached to running block.

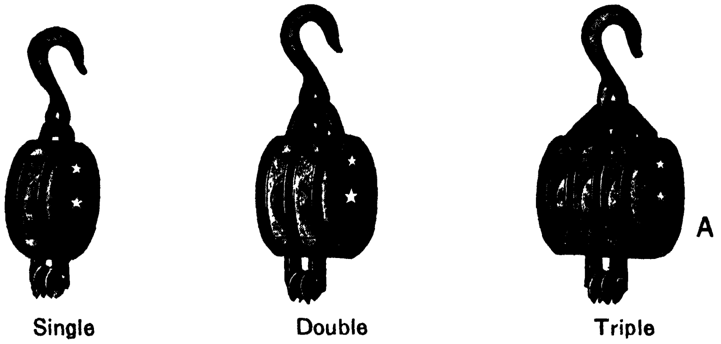
running block has two sheaves. The extra sheave in the standing block does not increase the mechanical advantage. It does make it possible, though, to change the direction of force. If the standing block did not have the extra sheave, the principle that the number of supporting ropes and mechanical advantage are *odd* numbers still would hold. In this arrangement it will be seen that to move the 5-lb. object a force of only 1 pound is needed. Further, to move the 5-lb. object 1 foot, the 1-lb. force would have to move 5 feet. The mechanical advantage is 5 divided by 1, or 5.

Note that the formula for figuring *MA* is merely approximate, for no allowance is made for the friction of the sheaves on their shafts or of the ropes passing over the sheaves. To obtain a more accurate *MA*, allowance for this friction must be made in the calculations.

Standard blocks. In general, blocks are described by length of the shell in inches, and the number of sheaves. Blocks having 1, 2, 3, or 4 sheaves are called, respectively, *single*, *double*, *triple*, and *quadruple*. Sometimes they are designated as, respectively, *single*, *two-fold*, *three-fold*, and *four-fold*. (See Fig. 7–41.) A block should never be smaller (length in inches) than approximately 9 times the rope diameter. Whenever possible, self-lubricating blocks should be used. This type contains graphite to permit the sheaves to roll smoothly and easily over the sheave pins. Therefore this type should never be oiled or greased.

The following table gives the specifications for the use of some common blocks.

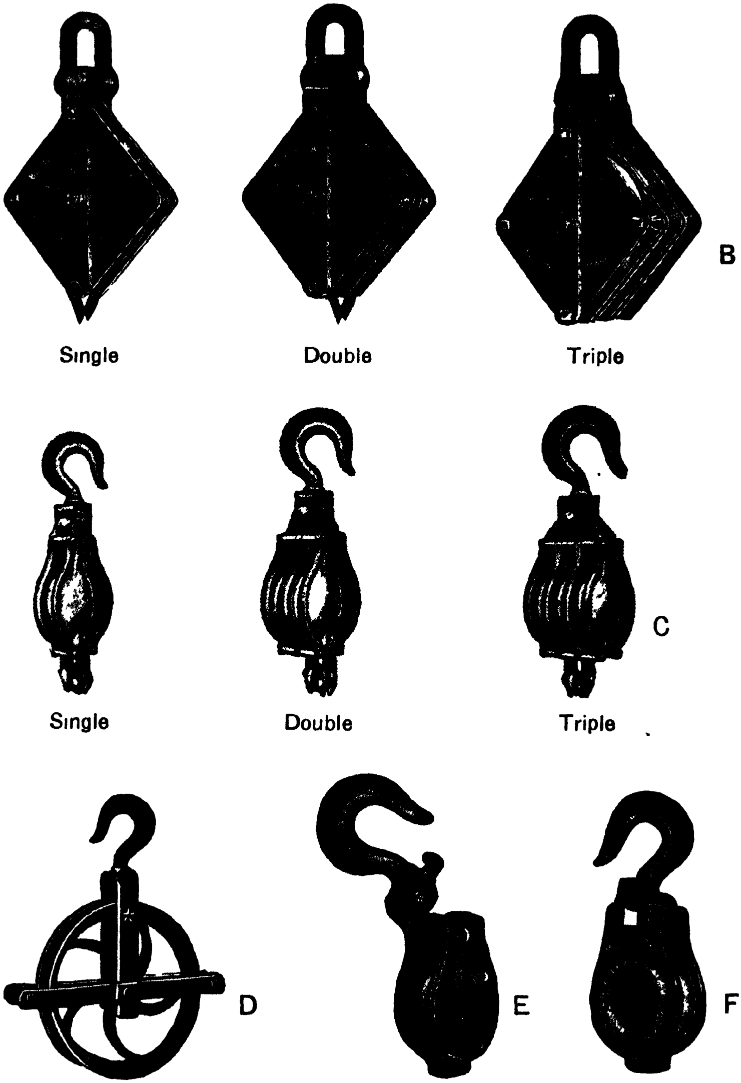
Size of block (length of shell in inches)	Number of sheaves	Maximum working strength of hook in pounds	Size of rope in inches	Suggested length of rope in feet	Maximum load for new rope, smaller size	Maximum load for new rope, larger size
3	1	2,100	$\frac{3}{8}$ or $\frac{1}{2}$	50	400	700
3	2	2,300	$\frac{3}{8}$ or $\frac{1}{2}$	75	400	600
3	3	3,900	$\frac{3}{8}$ or $\frac{1}{2}$	100	400	650
4	3	4,600	$\frac{1}{2}$ or $\frac{5}{8}$	150	700	800
6	3	8,600	$\frac{3}{4}$	200	1,400	
8	3	12,000	1	275	2,300	



Single Double Triple

Courtesy Boston & Lockport Block Co.

FIG. 7–41. Different types of blocks.



Courtesy Boston & Lockport Block Co.

FIG. 7-41. Different types of blocks.

Generally blocks are supplied with open hooks unless shackles are specified. A *shackle* is a U-shaped link which is attached to the block by a bolt and nut passing through its open ends and the center strap.

The load should always be applied to the hook at the place of greatest curvature. If not, the side of the hook will act as a lever to force open the curved hook and, therefore, will not be able to support the maximum load. When the hook begins to spread, the block should be replaced with a new hook before it is used again. Never force a spread hook back into its original shape and then use the block. The metal of a spread hook has lost its original and maximum strength and will never regain it until properly treated in the factory or machine shop.

The hooks on standard and snatch blocks are made so that they begin to separate at approximately 70 per cent of the maximum load. This serves as a visible warning against overstressing.

5. SNATCH BLOCK

The snatch block is a single-sheave block whose shell can be opened on one side. With a snatch block, the rope at any point can be placed directly on the sheave by opening the shell. This does away with the need, as in the case of other blocks, of reeving through by beginning with the end of the rope.

Snatch blocks have a great variety of uses, such as on board ships, for stringing power-line wires, and in lumbering operations, and like other blocks they come in a variety of sheave and shell forms.

The following table shows the specifications for the two sizes of snatch blocks most commonly used.

Size of snatch block	Working strength of hooks in pounds	Maximum load in pounds	Size of rope; diameter in inches
6 inch	11,000	15,000	$\frac{5}{8}$ or $\frac{3}{4}$
8 inch	17,000	25,000	1 or $1\frac{1}{4}$

6. REEVING OF BLOCKS

In order to obtain the greatest mechanical advantage, prevent jamming of ropes, and thus avoid accidents and save time, blocks must be reeved properly.

When possible, the block should be reeved so that the fall line comes from the center of a triple block. This will cause the hoisting strain to come from the center of the block and thus prevent it from turning and causing the rope to be cut or rubbed on the block shell.

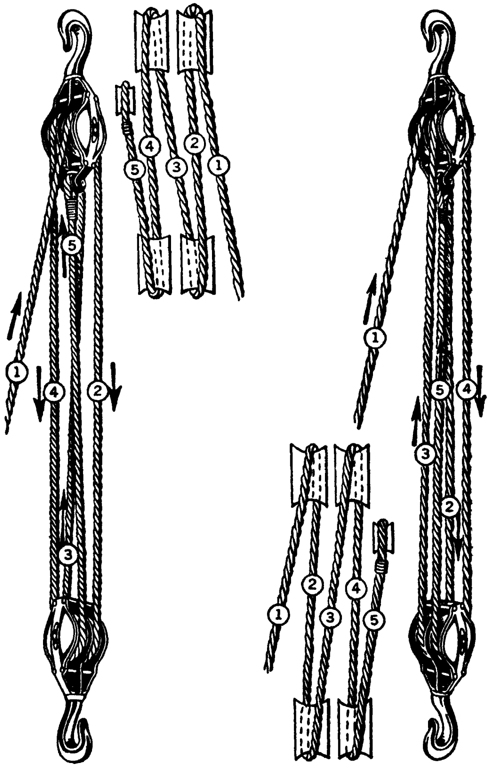


FIG. 7–42. Reeving two double blocks.

Study Figures 7–42, 7–43, and 7–44. These diagrams show how to reeve two double blocks, a double and a triple, and two triple blocks. For each combination two methods are shown, left over right and right over left. Either may be used.

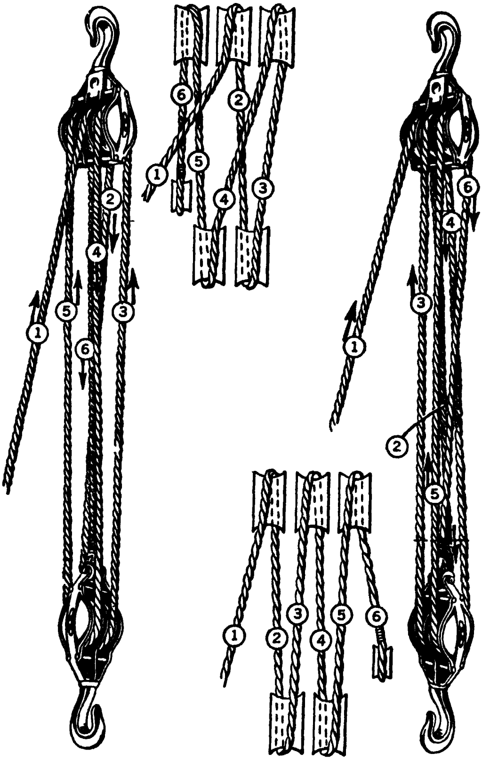


FIG. 7–43. Reeving a triple and double block.

In studying these illustrations note that the fall line is numbered 1. After passing over the first sheave of one block and coming down, it is numbered 2. After it passes around the first sheave of the second block, it is numbered 3, and so on. New rope, having more spring to it than old rope, should be placed

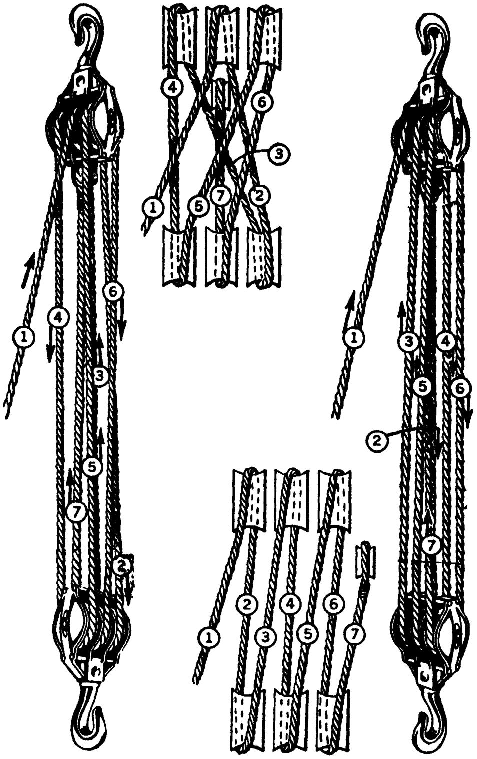


FIG. 7-44. Reeving two triple blocks.

under a slight tension when reeving. Reeving a snatch block was explained on page 406.

7. RIGGING

The use of rope in various block-and-tackle combinations in order to raise and to move heavy loads is called *rigging.* Whether one single block should be used, or two double blocks, or a double and a triple, or any other combination, and whether one or more sets of tackle should be used in the same operation depends on the weight to be raised or moved and the power available to do the work.

Luffing tackle. There are occasions when even if the mechanical advantage is 6 or 7, the pull required is greater than can be exerted by one man or even several men. Then, if no power machinery is available, *luffing tackle* is used. Luffing tackle is an additional tackle attached to the fall line of the main tackle to increase the mechanical advantage already provided by this first set of tackle. Figures 7–45 and 7–46 illustrate the use of luffing tackle for lifting a load and for hauling a load.

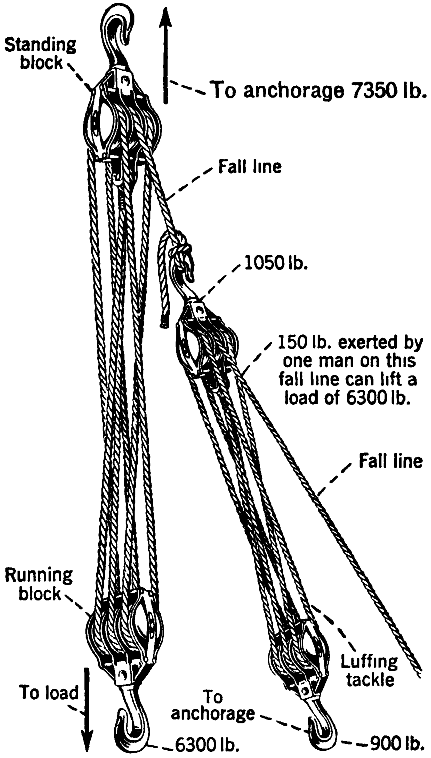


FIG. 7–45. Luffing tackle for lifting a load.

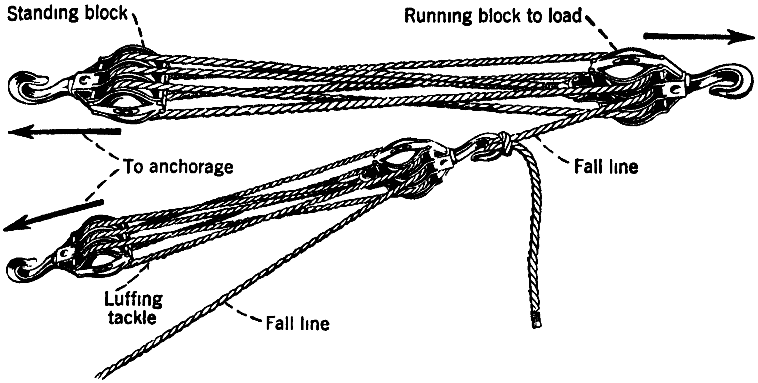


FIG. 7–46 Luffing tackle for hauling a load.

Let us refer to Figure 7–45. A load of 6300 lb. must be raised. Two triple blocks are used. The standing end is attached to the becket of the standing block. This allows for 6 lines of rope to support the running or load block. Then according to the explanation on page 402 the mechanical advantage is 6 and the amount of pull, not counting friction, needed on the fall line is 1050 lb. Naturally 1050 lb. is entirely too great a force to be exerted even by several men. For this case the luffing tackle consists of two triple blocks. The combination can be varied to suit particular needs. The running block of the luffing tackle is attached to the fall line of the first set of tackle. The standing block of the luffing tackle is attached to an anchorage.

The luffing tackle must handle a load of 1050 lb., that is, the force or pull needed on the first set of tackle. Since 7 lines of rope hold the running block of the luffing tackle, only 1050 lb., divided by 7, or 150 lb. of pull or force are needed on the fall line of the luffing tackle.

Thus, by using one set of tackle helped by an additional or auxiliary set called luffing tackle, a 6300-lb. load can be lifted by one man exerting 150 lb. of force. This is a mchanical advantage of 42.

8. SIZE OF BLOCKS (SELECTION)

How do we know that in the foregoing incident we had to use tackle made of triple blocks helped by luffing tackle, consisting of two other triple blocks? As explained on pages 402–403, we must know what the load is and what the power is. We know that the load is 6300 lb. and that 1 man was available for power. He could exert a force of at least 150 lb. We begin to solve the problem by using the following formula:

$$\text{Number of sheaves required in blocks} = \frac{\text{load}}{2 \times \text{effort}}$$

Thus, in this problem the number of sheaves required in each block equals 6300 lb. divided by twice 150 lb., or 6300 divided by 3000. This equals 21 sheaves.

In practice, however, blocks with more than 3 sheaves are rarely used. Therefore, as soon as the answer is more than 3, using the formula, we know that luffing tackle must be used.

Thus far we know that the first set of tackle must consist of two triple blocks. The next step in the solution of our problem is to find out what kinds of blocks should be used in the luffing tackle.

From our previous study we learned that the mechanical advantage is at least 6 for 2 triple blocks. Therefore the man can exert a force of 6 times 150 lb. or 900 lb. Again with the formula we employed before, but this time using the increased effort of the man provided by the first set of tackle, we find the following for the luffing tackle:

$$\text{Number of sheaves} = \frac{6300}{2 \times 900} = \frac{6300}{1800} = 3 +$$

Therefore, the luffing tackle must consist of 2 triple blocks. If the standing end of the luffing rope is attached to the running tackle, the mechanical advantage will be 7. A man with 150 lb. of force can move a load of 150 × 7 or 1050 lb. This, we found, was the amount of effort needed on the fall line of the first set of tackle.

Naturally, care must be exercised to select blocks having hooks that are strong enough. Thus, in the example just given, the hook of the standing block of the first tackle must resist a force of at least 7350 lb. This figure was obtained by adding together the load and the force or effort needed on the standing line. In this case it consists of 6300 lb. plus 1050 lb., or 7350 lb.

In the case of the luffing tackle, it is the hook of the running block that will have to resist the greatest force — 1050 lb. Since 150 lb. of effort will be exerted on the fall line, 1050 minus 150, or 900 lb., is the amount of resistance that will have to be met by the hook of the running block of the luffing tackle.

Instead of a man doing the pulling, what happens if there is an electric or gasoline motor or a truck to do the pulling? The machine has an effort of shall we say 2000 lb. Employing the formula we find:

$$\text{Number of sheaves} = \frac{6300}{2 \times 2000} = \frac{6300}{4000} = 1 +$$

The plus indicates part of a sheave. Since this is impossible, the next highest number of sheaves is the answer — use double blocks.

9. SAFETY PRECAUTIONS

The strength and safety of tackle may be compared with those of a chain — as strong as its weakest link. To continue the comparison we may say that tackle in use consists of three links: rope, blocks, and anchorage of standing block. Any two of these, no matter how strong they are, are as weak as the third. Each of them must have a maximum strength much greater than the weight to be moved. The one that is weakest will be the one to give way on strain, no matter how strong the other two are.

We studied on pages 359–367 the factors relating to the proper care and use of rope. Naturally, everything that was said there about the general use and care of rope applies particularly here in the use of tackle.

In addition, the following safety precautions should be observed to insure against loss of life, limb, and property.

(1) Always use blocks with swallows and breeches large enough for the free passage of rope. Blocks with sheave openings that are too small will cause the rope to wear out quickly from unnecessary rubbing, and will require extra force or effort to move the object because of unnecessary friction. Further, they weaken rope by forcing it to bend sharply as it passes through the block. Always use the proper size block with the rope necessary for the job. (See table on page 404.)

(2) Never stand unnecessarily close to rope that is under tension. Never straddle such rope. If rope held taut should suddenly part, the free ends can whip out with a blow so tremendous that it might cause permanent injury or even death.

(3) Always stand outside the angle and path of rope being paid out or under tension.

(4) Always attach the standing block to a support that is much stronger than the load to be moved. No matter how strong the rope and blocks may be, the anchorage will give way if it cannot resist the weight of the object.

(5) Make sure that the rope and the type of knot or lashing used to attach the hook to the object or to the rigid support are strong enough to more than equal the maximum resisting force.

(6) Whenever possible, wear gloves or leather hand pads when handling rope, especially new rope, to avoid splinters, cuts, and other injury from fiber slivers.

(7) Whenever possible, place rope on highways and thoroughfares where it will not be an obstruction. When it is impossible to do this, always have someone on hand to warn traffic.

(8) A hand line or other rope secured aloft to raise and lower tools and materials, should be secured near the ground when not in use, to prevent it from being blown about.

(9) A hand line should never be tied to any part of the body of a man working aloft on a pole. It should be secured to a pro-

jection such as the cross-arm or to the pole itself. Someone may unintentionally tug a hand line and if it is attached to the man working aloft it may dislodge him from his position.

(10) Inspect each block before using it.

(11) Reeve blocks properly. (See pages 407–409.) Improper reeving may prevent obtaining full mechanical advantage, the chief reason for using tackle. It may cause the load to weight one side of the block more than the other, forcing the rope to rub on the shell. It may cause the lines in the return to keep rubbing on each other.

F. ANALYSIS OF ROPES, SPLICES, AND KNOTS

This is a summary of rope shopwork — a sort of bird's-eye view of the things you should be able to do, the things you should know, and some suggested work to help you apply both your skill and your knowledge.

For every item of knowledge and every type of skill mentioned, try to know the *why, how, when,* and *where.* These have been covered in the unit. Knowledge and skill based on such a good foundation will last long. It will enable you to solve the problems of new situations in rope shopwork and provide the basis for more advanced and specialized study in this field.

The knowledge and skills described here have been found necessary in a great variety of occupations in the armed forces. Eighty per cent of these occupations are exactly like jobs in regular civilian life. A mastery of these highlights of rope shopwork will be valuable in both civilian and military jobs, and in peace as well as in war.

THINGS YOU SHOULD BE ABLE TO DO	THINGS YOU SHOULD KNOW	SUGGESTED JOBS, PROJECTS, AND EXERCISES
SPLICES: Serve a splice, 367–370.	The service splice is used to wrap binding on the end of a rope against the lay to prevent unlaying, 367–370.	Whip the end of a rope.
Make an eye splice, 372–373.	The length of the rope required is 1½ times the circumference of the eye, 372.	Fasten a rope end to a metal ring.
Make a short straight splice, 373–375.	A short splice is used where an increase in the diameter at the point of splice is not objectionable, 373.	Lengthen a line by joining two ropes.
Make a long straight splice, 376–378.	Since there is no increase in diameter, this splice permits the rope to run through a block, 376.	Repair a line by cutting out damaged sections of a rope and splicing it together again.
KNOTS: Make a figure-eight knot, 380–381.	This knot can be used to prevent a rope from going through a block. It can also be used to provide a grip on a rope, 380–381.	Knot the ends of a towline.
Make a single-sheet bend, 381–382.	This knot is the same as a block-becket bend, 381–382.	Join together two ropes of different diameter sizes.
Make a square knot, 382–383.	This is the knot most commonly used for joining ropes, 382.	Join together two ropes of the same diameter size.
Make a bowline single, 383–385.	Knots must be easily tied and untied, 383.	Make a loop that will not slip.
Make a double bowline on a bight, 385–389.	Doubling increases strength and permits the use of a rope without disturbing the ends, 385–386.	Make a comfortable sling for a man (safety seat).

Things You Should Be Able To Do	Things You Should Know	Suggested Jobs, Projects, and Exercises
Make two half-hitches, 389–390.	The end may be lashed down or seized to standing part to prevent slipping, 389.	Make a rope fast to a ring or post.
Make a clove hitch, 389–391.	This knot is a form of two jammed half-hitches, 389.	Fasten a rope at right angles to a spar or post. Begin a lashing.
Make lashings, 394.	Lashings are used to lash poles or spars together, 394.	Lash three poles together to form a tripod.
Blocks:		
Reeve a single sheave block, 406.	The parts of a block (swallow, breech, etc.), 396–398.	Rig a simple tackle.
Reeve a double block, 407–408.	How to determine loads and required efforts, 404, 406, and 412–413.	Rig a tackle with double sheave blocks.
Reeve a three-sheave block, 408–409.	The fall end of the line must go through the center sheave, 407.	Rig a tackle with a luffing tackle to increase effort.

SUMMARY

1. Rope was one of the earliest materials used by man. Our ancestors made use of rope for dragging, lifting, and tying things together, before history was recorded. After a time they learned to twist, weave, and braid rope materials to make stronger and longer ropes.

2. Rope made of plant fibers is the kind nearly always used. It is flexible and can be adapted for many purposes. Metal rope, made of twisted strands or wires, is used only rarely.

3. Of the thousands of plants whose fibers can be used in making rope, the most common is hemp. One of the best for hard usage —

for instance, marine or construction work — is manila hemp from the Philippines. It is also one of the strategic materials (necessary for carrying on a successful war) which cannot be produced in our own country.

4. The fibers which are twisted together in rope are held together by friction. This would not be possible unless the fibers were twisted in one direction, and the resulting strands twisted in the opposite direction.

5. Rope must have good care, for breaking rope can cause loss of life as well as costly damage to buildings and materials. Rope is usually shipped in coils.

6. Many kinds of knots may be tied in ropes, but about ten of the simplest ones will suffice for most purposes. One of these ten, the bowline knot, has dozens of varieties, but there are five bowline knots which are most useful.

7. The art of splicing lengths of rope together and of using splices to protect loose ends is important to anyone working with rope. Splicing gives a stronger rope than knotting does.

8. Blocks and pulleys help in the efficient use of rope and they also avoid too great strain on the rope itself.

How many of the following terms can you define or explain?

Manila hemp
Coir rope
Against the lay
Small cordage
Hawser
Crown splice
Half-hitch
Bowline knot
Breaking strain
Thumb knot
Shackle
Guy rope
Standing block
Luffing tackle
Sheave

SELF-TESTING EXERCISES

Answer These Questions

On a separate sheet of paper numbered from 1 to 6 write the letters for the phrases that answer the following questions correctly.

1. What is the effect of strain on the parts of a rope that has been properly twisted? (*a*) They tend to unravel; (*b*) they wear out quickly; (*c*) they become stronger and tighter; (*d*) they drag.

2. What is the name of the kind of rope made by laying together three ropes to form one of larger diameter? (*a*) Cordage; (*b*) cable; (*c*) hawser; (*d*) plain-laid rope.

3. How would you start coiling rope that is full of twists and turns? (*a*) Against the lay; (*b*) counterclockwise; (*c*) with the lay; (*d*) with an overhand loop.

4. How many sheaves does a triple block have? (*a*) 9; (*b*) 3; (*c*) 5; (*d*) 2.

5. What is the effect of using blocks that have unusually small sheave openings, considering the rope to be used? (*a*) They wear out the rope; (*b*) they hold the rope firmly; (*c*) they speed up the action.

6. How strong should be the support to which the standing block is attached? (*a*) As strong as the rope and blocks; (*b*) half as strong as the load; (*c*) stronger than the load.

Complete These Statements

On a separate sheet of paper numbered from 1 to 11 write the words needed to fill correctly the blank spaces in the following sentences.

Sisal rope which is grown in Mexico is (1) . than manila rope. In making rope the fibers are first twisted to the (2) . to make yarns or threads; then twisted to the . (3) . to make strands; the strands are then twisted to the (4). to make the rope. If the strands of a rope slope from upper right to lower left, the direction or lay of the rope is (5) . The formula for working strain of hemp rope is $\frac{C^2}{9}$ = tons. The formula for the safe working strain of the same kind of rope is (6) .. It is especially important to do everything to increase the life of rope during World War II because it is a ..(7). material. For permanently joining two lengths of rope ..(8). are better than knots. Acids have a . (9).. effect on rope fibers. A disadvantage of the short straight splice is that that part of the rope is ..(10).. than the rest. The simplest of all the knots is the ..(11).. knot.

QUESTIONS

1. What are some of the methods used by manufacturers to strengthen rope so as to avoid rotting?

2. What would happen if fibers, yarns, and strands were all twisted in the same direction?

3. Using the formula, $B.S. = \frac{C^2}{3}$, find the number of tons of strain which a hemp rope 5 inches in circumference will stand without breaking.

4. Describe as fully as possible how you would make a short straight splice.

5. For what purposes are the four general classes of knots used?

6. What are some safety precautions to remember in dealing with rope? Name five.

APPLICATIONS

1. Make an index-card dictionary of rope terms.

2. Make a scrapbook on rope. Include items relating to names and sizes of rope, to rope splicing, rope knotting, types of block, precautions in the use of tackle; on the care required to protect rope, including worming, parceling, and serving. Be on the alert for newspaper and magazine articles on rope. You can get further information by watching men at work on large building projects, and by observing the use of ropes on farms and in quarries and mines, or on docks.

3. Master each of the splices described in this unit. Master each one before you proceed with another. The best proof of mastery is the ability to tie each splice under a table, hidden from your eyes, or in a dark room.

4. Make a chart with real rope and worded information to show what is meant by right-laid, left-laid, small stuff, rope, plain-laid, hawser, cable-laid. Perhaps you can join with several of your fellow students to do this job.

5. Master each of the knots described in this unit. Do not try to learn them all at one time. You will only become confused. As with splices, the best proof of mastery is to tie each knot when it is hidden from your eyes. Make a display of the various knots described by tying each one and mounting it on a black cardboard properly labeled.

6. Your teacher will give you a block that has been discarded because it may cause an accident if it is used. Examine the block carefully and list all the parts that are damaged. Explain for each why you would reject the block and tell what harm each could cause if the block were used.

7. Reeve two triple blocks as shown in Fig. 7–44. Reeve a triple and double block as shown in Fig. 7–43.

8. A weight of 8000 lb. must be lifted. Two men are available to do the pulling, each able to exert a force of 150 lb. By diagrams explain what tackle should be used to do the job.

9. Worm, parcel, and serve a three-foot length of rope.

10. Look about your home, school, shop, and elsewhere, as along the docks, in the commercial district, and on a farm. Note as many uses as possible for cord and rope and tell what kinds of knots are used.

11. Sketch the arrangement of tackle using standing and running blocks where the *MA* is 3.

12. Make a display of the various splices by tying each splice and mounting it on a black cardboard properly labeled.

13. Practice coiling and uncoiling rope until your teacher says that you have mastered this important job.

14. If possible, go to a museum of science, art, or industry and write short notes or make rough sketches of as many instances as you can showing how and where blocks are used.

15. The standing end of the rope is attached to the standing block. The object to be moved weighs 100 lb. The force is 25 lb. How many sheaves are there in each block? How many ropes support the running block? For each foot the object moves, how far will the force have to move? Explain your answer with a diagram.

APPENDIX

A

Tables

TABLE 1. — USEFUL NUMBERS

12 in.	= 1 ft.	3 ft.	= 1 yd.
16½ ft.	= 1 rd.	320 rd.	= 1 mi.
5280 ft.	= 1 mi.	144 sq. in.	= 1 sq. ft.
9 sq. ft.	= 1 sq. yd.	1728 cu. in.	= 1 cu. ft.
27 cu. ft.	= 1 cu. yd.	2150.4 cu. in.	= 1 bu.
231 cu. in.	= 1 gal.	60 mi. per hr.	= 88 ft. per sec.
1 lb. avoir.	= 7000 gr.	1 lb. Troy	= 5760 gr.
1 oz. avoir.	= 437.5 gr.	1 oz. Troy	= 480 gr.
1 cu. ft. of water weighs 62.4 lb.		π^2	= 9.86965
Circumference of a circle	= $2\pi r$	Area of circle	= πr^2, or $\frac{1}{4}\pi d^2$
Surface of sphere	= $4\pi r^2$	Volume of sphere	= $\frac{1}{6}\pi d^3$

TABLE 2. — METRIC–ENGLISH EQUIVALENTS

1 in.	= 2.5399 cm.	1 ft.	= 30.479 cm.
1 mi.	= 1609.3 m.	1 mi.	= 1.6093 km.
1 mm.	= .03937 in.	1 cm.	= .3937 in.
1 m.	= 39.3708 in.	1 m.	= 3.2809 ft.
1 m.	= 1.0936 yd.	1 sq. cm.	= 0.155 sq. in.
1 sq. in.	= 6.451 sq. cm.	1 cu. in.	= 16.3862 cc.
1 lb.	= 453.593 gm.	1 kgm.	= 2.2046 lb.
1 oz.	= 28.3495 gm.	1 gm.	= 15.432 gr.

TABLE 3. — DECIMAL EQUIVALENTS OF 8THS, 16THS, 32DS, AND 64THS OF AN INCH

8ths

1/8 = .125
1/4 = .250
3/8 = .375
1/2 = .500
5/8 = .625
3/4 = .750
7/8 = .875

16ths

1/16 = .0625
3/16 = .1875
5/16 = .3125
7/16 = .4375
9/16 = .5625
11/16 = .6875
13/16 = .8125
15/16 = .9375

32ds

1/32 = .03125
3/32 = .09375
5/32 = .15625
7/32 = .21875
9/32 = .28125
11/32 = .34375
13/32 = .40625
15/32 = .46875
17/32 = .53125
19/32 = .59375
21/32 = .65625
23/32 = .71875
25/32 = .78125
27/32 = .84375
29/32 = .90625
31/32 = .96875

64ths

1/64 = .015625
3/64 = .046875
5/64 = .078125
7/64 = .109375
9/64 = .140625
11/64 = .171875
13/64 = .203125
15/64 = .23437
17/64 = .265625
19/64 = .296875
21/64 = .328125
23/64 = .359375
25/64 = .390625
27/64 = .421875
29/64 = .453125
31/64 = .484375
33/64 = .515625
35/64 = .546875
37/64 = .578125
39/64 = .609375
41/64 = .640625
43/64 = .671875
45/64 = .703125
47/64 = .734375
49/64 = .765625
51/64 = .796875
53/64 = .828125
55/64 = .859375
57/64 = 890625
59/64 = .921875
61/64 = .953125
63/64 = .984375

TABLE 4. — APPROXIMATE DRYING PERIODS FOR 1″ LUMBER

Species	Air-seasoned Stock to 20%	Days required Kiln-dried Stock		Green to 12% (Airplane)
		20% to 6%	Green to 6%	
Upland white oak	240 to 300	6 to 12	20 to 45	25 to 35
Upland red oak	180 to 240	4 to 8	16 to 26	20 to 30
Lowland oak	360 to 400	6 to 14	20 to 50	40 to 60
Birch	150 to 200	5 to 8	11 to 15	15 to 20
Beech	150 to 200	6 to 8	12 to 15	16 to 20
Maple	150 to 200	5 to 7	10 to 14	15 to 19
Ash	70 to 110	4 to 7	12 to 18	16 to 20
Gum red	100 to 160	8 to 10	16 to 24	20 to 28
Gum sap	70 to 110	5 to 7	12 to 18	18 to 22
Hickory	150 to 200	8 to 14	20 to 40	25 to 32
Elm	80 to 130	4 to 6	10 to 15	15 to 20
Yellow poplar	40 to 70	4 to 6	10 to 13	15 to 18
Basswood	30 to 60	3 to 5	7 to 10	11 to 14
Cherry	150 to 200	5 to 7	10 to 12	15 to 18
Chestnut	85 to 125	4 to 8	8 to 12	10 to 13
Walnut	120 to 170	6 to 8	12 to 18	16 to 20
Mahogany	70 to 110	4 to 7	12 to 16	16 to 20
Magnolia	60 to 100	4 to 6	10 to 16	15 to 20
Tupelo	70 to 110	5 to 7	12 to 18	16 to 20
Southern yellow pine	40 to 70		2½ to 4	8 to 10
Western yellow pine	45 to 90		3 to 5	...
Douglas fir	40 to 70		2 to 4	8 to 10
Northern white pine	60 to 150		4 to 5	...
Western white pine	45 to 90		3 to 5	...
Sugar pine	45 to 90		4 to 5	
Sitka spruce	45 to 90		4 to 7	8 to 10
Redwood	60 to 180		7 to 10	...
Cypress	200 to 275		6 to 10	14 to 18
White fir	45 to 90		3 to 5	...
Western hemlock	60 to 120		3 to 5	...
Western red cedar	50 to 140		10 to 15	...

TABLE 5.—BROAD CLASSIFICATION TO CHARACTERISTICS

[A, among the woods relatively high in the particular respect listed; B, among the woods particular

Kind of Wood	Working and Behavior Characteristics										Strength Properties				
	Hardness	Weight, dry	Freedom from shrinkage	Freedom from warping	Ease of working	Paint holding	Nail holding	Decay resistance of heartwood	Proportion[1] of heartwood	Amount of figure	Freedom from odor and taste (dry)	Bending strength	Stiffness	Strength as a post	Toughness
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ash:															
White	A	A	B	B	C		A	C	C	A	A	A	A	A	A
Black	A	B	C	B	C			C	C	A		B	B	C	A
Basswood	C	C	C	B	A		C	C	C	C	A	C	B	C	C
Beech	A	A	C	C	C		A	C	B	B	A	A	A	B	A
Birch, yellow	A	A	C	B	C		A	C	C	B	A	A	A	B	A
Cedar:															
Northern white	C	C	A	A	A	A	C	A	A	C	C	C	C	C	C
Southern white	C	C	A	A	A	A		A	A	C	C	C	C	C	C
Western red	C	C	A	A	A	A	C	A	A	B	C	C	C	B	C
Eastern red	A	A	A	A	B			A	B	B	C	B	C	A	B
Cherry	A	B	B	A	C				B	B	B	A	A	A	B
Chestnut	B	B	B	A	B		B	A	A	A	B	C	C	C	B
Cottonwood	C	B	C	C	B		C	C	C	C	B	C	B	C	B
Cypress, southern	B	B	B	B	B	A	B	A	B	A	B	B	B	B	B
Douglas fir	B	B	B	B	C	C	B	B	A	A	C	A	A	A	B
Elm:															
Soft	A	A	C	C	C		A	B	B	A	A	B	B	B	A
Rock	A	A	C	B	C			B	B	A	A	A	A	B	A
Fir:															
Balsam	C	C	B	B	B	B		C	B	B	A	C	C	C	C
White	C	C	B	B	B	B	C	C	C	B	A	B	B	B	C
Gum, red	B	B	C	C	B		B	B	B	B	B	B	B	B	B
Hackberry	A	A	C	B	C				C	A	A	B	C	C	A
Hemlock:															
Eastern	B	B	B	B	B	B	B	C	B	B	A	B	B	B	B
Western	B	B	B	B	B	B	B	C	B	B	A	B	A	B	B
Hickory:															
True	A	A	C	B	C		A	C	B	B		A	A	A	A
Pecan	A	A	C	B	C			C	B	B		A	A	A	A

[1] Exclusive of the all-heartwood grades that are available on special order in birch,

OF WOODS ACCORDING AND PROPERTIES

intermediate in the particular respect listed; C, among the woods relatively low in the respect listed]

Surface Characteristics of Common Grades						Distinctive Uses	
Number of knots	Size of knots	Number of pitch defects	Size of pitch defects	Number of other defects	Size of other defects	Farm	Commercial
17	18	19	20	21	22	23	24
C	B	None		B	B	Handles, implements	Handles, vehicle parts
C	B	None		B	B	Implements	
C	B	None		C	C	Woodenware	Fixtures, furniture parts
B	B	None		A	A	Woodenware, containers, fuel	Woodenware, flooring, furniture parts
C	B	None		B	B	Millwork, furniture	Millwork, furniture
A	C	None		C	C	Posts, shingles	Posts, poles, boats, shingles
		None				Posts, poles, shingles	Boat and tank stock, poles
C	A	None		C	C	Shingles, siding, posts, and poles	Poles, shingles, siding
A	C	None		C	C	Posts	Chests, pencils
C	B	None				Furniture	Electrotype blocks
C	A	None		A	B	Poles, posts, trim	Caskets, poles, core stock
C	C	None		C	C	Wagon boxes, containers	Boxes, cases, and furniture parts
C	B	None		B	B	Silos, tanks, construction	Greenhouses, tanks, construction
B	B	B	B	B	B	Construction	Construction
B	B	None		A	A	Cheese boxes	Containers
B	B	None		B	B	Implements	Cooperage
A	C	None		B	B	Light construction	Pulpwood
B	B	None		B	A	Light construction	Light construction, pulpwood
C	B	None		C	C	Fruit and vegetable boxes	Furniture, millwork, containers
C	A	None		B	B	Furniture	Automobile bodies
B	B	None		A	A	Construction	Construction
B	B	None		B	B	Construction	Construction
B	A	None		B	B	Handles, implements	Implements, handles, sporting goods
C	A	None		A	A	Wagon and buggy parts	Furniture, automobile bodies

cedar, cypress, Douglas fir, red gum, southern yellow pine, redwood, and walnut.

TABLE 5

Kind of Wood	Working and Behavior Characteristics										Strength Properties				
	Hardness	Weight, dry	Freedom from shrinkage	Freedom from warping	Ease of working	Paint holding	Nail holding	Decay resistance of heartwood	Proportion[1] of heartwood	Amount of figure	Freedom from odor and taste (dry)	Bending strength	Stiffness	Strength as a post	Toughness
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Larch, western	A	A	B	B	C	C	A	B	A	A	C	A	A	A	B
Locust:															
Black	A	A	B	B	C		A	A	A	A	B	A	A	A	A
Honey	A	A	B	B	C		A	B	B	A	B	A	A	A	A
Maple															
Hard	A	A	C	B	C		A	C	C	B	A	A	A	A	A
Soft	A	A	B	B	C		A	C	C	B	A	C	C	C	C
Oak:															
Red	A	A	C	B	C		A	C	B	A		A	A	B	A
White	A	A	C	B	C		A	A	B	A		A	A	B	A
Pine:															
Ponderosa	C	B	B	A	A	B	B	(2)	C	C	C	C	C	C	C
Southern yellow	A	A	B	B	C	C	A	B	C	A	C	A	A	A	B
White pine group.															
Northern white	C	C	A	A	A	A	B	(2)	B	C	C	C	C	C	C
Western white	C	B	B	A	A	A	B	(2)	B	C	C	B	B	B	B
Sugar pine	C	C	A	A	A	A		(2)	B	C	C	C	C	C	C
Poplar, yellow	C	B	B	A	A		B	C	B	B	A	B	B	C	C
Redwood	B	B	A	A	B	A	B	A	A	B		B	B	A	B
Spruce:															
Eastern	C	B	B	A	B	B	B	C	C	B	A	B	B	B	B
Sitka	C	B	B	A	B	B		C	C	B	A	B	A	B	B
Engelmann	C	C	B	A	B	B	C	C	C	B	A	C	C	C	C
Sycamore	A	A	C	C	C		A	C	B	B		B	B	B	B
Tupelo	A	A	B	C	C		A	C	C	C	A	B	B	B	B
Walnut	A	A	B	A	B			A	B	B		A	A	A	A

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[1] Exclusive of the all-heartwood grades that are available on special order in birch, cedar,
[2] Conflicting opinion and absence of adequate test data preclude a definite rating; the

(continued)

SURFACE CHARACTERISTICS OF COMMON GRADES						DISTINCTIVE USES	
Number of knots	Size of knots	Number of pitch defects	Size of pitch defects	Number of other defects	Size of other defects	Farm	Commercial
17	18	19	20	21	22	23	24
A	C	C	C	A	C	Construction	Construction
B	B	None		B	B	Fence posts	Insulator pins
B	B	None		B	B		
B	B	None		B	B	Implements, flooring	Flooring, furniture, machine parts
C	B	None		C	C	Fuel	Furniture
C	A	None		B	B	Implement parts, construction	Furniture, flooring
C	A	None	B	B	B	Implement parts, posts, construction	Cooperage, furniture, flooring
B	B	B	B	B	B	Millwork, light construction	Millwork, planing-mill products, construction, boxes
C	A	A	A	B	B	Construction	Construction
A	C	C	C	B	B	Millwork, siding	Millwork, planing-mill products, containers
A	C	C	C	A	C	Millwork, siding	Millwork, planing-mill products, containers
A	B	C	C	B	C	Millwork	Patterns, millwork
C	B	None		C	C	Millwork	Millwork, furniture
C	A	None		C	B	Silos, tanks, construction	Tanks, planing-mill products, construction
A	C	C	C	B	B	Construction	Pulpwood, musical instruments
B	B	C	B	B	B	Ladders, construction	Airplanes, construction
A	C	C	C	B	B	Construction	Construction
C	B	None		B	B	Baskets and boxes	Boxes and crates, millwork
C	C	None		C	C	Fruit and vegetable boxes	Factory flooring, boxes and crates
C	B	None		C	C	Furniture	Furniture, millwork

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cypress, Douglas fir, red gum, southern yellow pine, redwood, and walnut
authors recommend against relying on high decay resistance when this wood is used untreated.

TABLE 6. — STANDARD DIMENSIONS FOR DRESSED LUMBER

	Lumber Described as Nominal	Actual Dimensions When Surfaced Shall Not Be Less Than —	Actual Dimensions When Rough Dry Shall Not Be Less Than —
	Inches	Inches	Inches
Thickness	1	25/32	29/32
	1 1/4	1 1/16	1 5/32
	1 1/2	1 5/16	1 13/32
	1 3/4	1 7/16	1 9/16
	2	1 5/8	1 3/4
	2 1/2	2 1/8	2 1/4
	3	2 5/8	2 3/4
	4	3 5/8	3 3/4
Width	3	2 5/8	2 3/4
	4	3 1/2	3 5/8
	5	4 1/2	4 5/8
	6	5 1/2	5 5/8
	7	6 1/2	6 5/8
	8	7 1/4	7 3/8
	9	8 1/4	8 3/8
	10	9 1/4	9 3/8
	11	10 1/4	10 3/8
	12	11 1/4	11 3/8

TABLE 7. — NAIL SIZES ACCORDING TO THE PENNY SYSTEM

Size	Length (inches)	Gage Number			
		Common nail	Casing	Finishing	Common brad
2d	1	15	. . .	. . .	15
3d	1 1/4	14	14 1/2	15 1/2	14
4d	1 1/2	12 1/2	14	15	12 1/2
5d	1 3/4	12 1/2	14	15	12 1/2
6d	2	11 1/2	12 1/2	13	11 1/2
7d	2 1/4	11 1/2	12 1/2	13	11 1/2
8d	2 1/2	10 1/4	11 1/2	12 1/2	10 1/4
9d	2 3/4	10 1/4	11 1/2	. . .	10 1/4
10d	3	9	. . .	. . .	9
12d	3 1/4	9	. . .	. . .	9
16d	3 1/2	8	. . .	. . .	8
20d	4	6	. . .	. . .	6

TABLE 8. – SCREW CLEARANCE-HOLE, PILOT-HOLE, AND COUNTERBORING SIZES

Gage No.	Clearance Hole		Pilot Hole				Counter-boring
			Hardwood		Softwood		
	Twist bit inches	Twist drill # or letter	Twist bit inches	Twist drill #	Twist bit inches	Twist drill #	Inches
0	1/16	52	1/32	70	1/64	75	.
1	5/64	47	1/32	66	1/32	71	. .
2	3/32	42	3/64	56	1/32	65	3/16
3	7/64	37	1/16	54	3/64	58	4/16
4	7/64	32	1/16	52	3/64	55	4/16
5	1/8	30	5/64	49	1/16	53	4/16
6	9/64	27	5/64	47	1/16	52	5/16
7	5/32	22	3/32	44	1/16	51	5/16
8	11/64	18	3/32	40	5/64	48	6/16
9	3/16	14	7/64	37	5/64	45	6/16
10	3/16	10	7/64	33	3/32	43	6/16
11	13/64	4	1/8	31	3/32	40	7/16
12	7/32	2	1/8	30	7/64	38	7/16
14	1/4	D	9/64	25	7/64	32	8/16
16	17/64	I	5/32	18	9/64	29	9/16
18	19/64	N	3/16	13	9/64	26	10/16
20	21/64	P	13/64	4	11/64	19	10/16
24	3/8	V	7/32	1	3/16	15	12/16

TABLE 9. — STANDARDS FOR WIRE GAGES

(In Use in the United States)

Dimensions of Sizes in Decimal Parts of an Inch

Number of Wire Gage	American or Brown & Sharpe	Birmingham or Stubs' Iron Wire	Washburn & Moen, Worcester, Mass.	W. & M. Steel Music Wire	American S. & W. Co.'s Music Wire Gage	Imperial Wire Gage	Stubs' Steel Wire	U. S. Standard Gage for Sheet and Plate Iron and Steel	Number of Wire Gage
00000000	......	...	...	.0083	..	...	...	....	00000000
0000000	......	..	.....	.0087	..	.	..	.....	0000000
000000	......	....	.....	.0095	.004	.464	....	.46875	000000
00000	......	....	.....	.010	.005	.432	...	.4375	00000
0000	.460	.454	.3938	.011	.006	.400	...	.40625	0000
000	.40964	.425	.3625	.012	.007	.372	...	.375	000
00	.3648	.380	.3310	.0133	.008	.348	...	.34375	00
0	.32486	.340	.3065	.0144	.009	.324	..	.3125	0
1	.2893	.300	.2830	.0156	.010	.300	.227	.28125	1
2	.25763	.284	.2625	.0166	.011	.276	.219	.265625	2
3	.22942	.259	.2437	.0178	.012	.252	.212	.250	3
4	.20431	.238	.2253	.0188	.013	.232	.207	.234375	4
5	.18194	.220	.2070	.0202	.014	.212	.204	.21875	5
6	.16202	.203	.1920	.0215	.016	.192	.201	.203125	6
7	.14428	.180	.1770	.023	.018	.176	.199	.1875	7
8	.12849	.165	.1620	.0243	.020	.160	.197	.171875	8
9	.11443	.148	.1483	.0256	.022	.144	.194	.15625	9
10	.10189	.134	1350	.027	.024	.128	.191	.140625	10

11	.090742	.120	.1205	.0284	.026	.116	.188	.125	11
12	.080808	.109	.1055	.0296	.029	.104	.185	.109375	12
13	.071961	.095	.0915	.0314	.031	.092	.182	.09375	13
14	.064084	.083	.0800	.0326	.033	.080	.180	.078125	14
15	.057068	.072	.0720	.0345	.035	.072	.178	.0703125	15
16	.05082	.065	.0625	.036	.037	.064	.175	.0625	16
17	.045257	.058	.0540	.0377	.039	.056	.172	.05625	17
18	.040303	.049	.0475	.0395	.041	.048	.168	.050	18
19	.03589	.042	.0410	.0414	.043	.040	.164	.04375	19
20	.031961	.035	.0348	.0434	.045	.036	.161	.0375	20
21	.028462	.032	.03175	.046	.047	.032	.157	.034375	21
22	.025347	.028	.0286	.0483	.049	.028	.155	.03125	22
23	.022571	.025	.0258	.051	.051	.024	.153	.028125	23
24	.0201	.022	.0230	.055	.055	.022	.151	.025	24
25	.0179	.020	.0204	.0586	.059	.020	.148	.021875	25
26	.01594	.018	.0181	.0626	.063	.018	.146	.01875	26
27	.014195	.016	.0173	.0658	.067	.0164	.143	.0171875	27
28	.012641	.014	.0162	.072	.071	.0149	.139	.015625	28
29	.011257	.013	.0150	.076	.075	.0136	.134	.0140625	29
30	.010025	.012	.0140	.080	.080	.0124	.127	.0125	30
31	.008928	.010	.0132	.	.085	.0116	.120	.0109375	31
32	.00795	.009	.0128	.	.090	.0108	.115	.01015625	32
33	.00708	.008	.0118	.	.095	.0100	.112	.009375	33
34	.006304	.007	.0104	.	. . .	.0092	.110	.00859375	34
35	.005614	.005	.0095	.	. . . .	.0084	.108	.0078125	35
36	.005	.004	.0090	. .	. .	.0076	.106	.00703125	36
37	.004453		.		. .	.0068	.103	.006640625	37
38	.003965	.		. .		.0060	.101	.00625	38
39	.003531	.	.			.0052	.099	. . . .	39
40	.003144	.	.	.		.0048	.097	. . . . .	40

TABLE 10. — SCREW DIAMETERS AND LENGTHS

LENGTH IN INCHES	DIAMETER IN WIRE-GAGE SIZE																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	24
¼	×	×	×	×																		
⅜			×	×	×	×	×	×														
½		×	×	×	×	×	×	×	×													
⅝				×	×	×	×	×	×	×	×											
¾					×	×	×	×	×	×	×	×										
⅞							×	×	×	×	×	×	×									
1							×	×	×	×	×	×	×		×							
1¼								×	×	×	×	×	×		×		×					
1½							×	×	×	×	×	×	×		×		×		×			
1¾									×	×	×	×	×		×		×		×	×		
2									×	×	×	×	×		×		×		×	×		
2¼										×	×	×	×		×		×		×	×		
2½													×		×		×		×	×		
2¾															×		×		×	×		
3																	×		×	×		
3½																			×	×		×
5																						×

TABLE 11.—AMERICAN NATIONAL STANDARD SCREW THREAD PITCHES AND RECOMMENDED TAP DRILL SIZES

American National Coarse Standard Thread (N. C) (formerly U. S. standard)					American National Fine Standard Thread (N. F.) (formerly SAE thread)				
Sizes	Threads per inch	Outside diameter of screw	Tap drill sizes	Decimal equivalent of drill	Sizes	Threads per inch	Outside diameter of screw	Tap drill sizes	Decimal equivalent of drill
1	64	.073	53	0595	0	80	060	3/64	0469
2	56	.086	50	.0700	1	72	073	53	0595
3	48	.099	47	.0785	2	64	.086	50	.0700
					3	56	.099	45	.0820
4	40	.112	43	0890	4	48	.112	42	0935
5	40	125	38	.1015	5	44	.125	37	.1040
6	32	.138	36	.1065	6	40	.138	33	.1130
8	32	.164	29	1360	8	36	.164	29	1360
10	24	.190	25	1495	10	32	190	21	.1590
12	24	216	16	1770	12	28	.216	14	.1820
1/4	20	250	7	2010	1/4	28	.250	3	2130
5/16	18	.3125	F	2570	5/16	24	3125	I	.2720
3/8	16	.375	5/16	3125	3/8	24	375	Q	3320
7/16	14	4375	U	3680	7/16	20	4375	25/64	3906
1/2	13	.500	27/64	4219	1/2	20	500	29/64	4531
9/16	12	.5625	31/64	4843	9/16	18	5625	5062	5062
5/8	11	625	17/32	.5312	5/8	18	625	5687	.5687
3/4	10	.750	21/32	.6562	3/4	16	.750	11/16	6875
7/8	9	.875	49/64	.7656	7/8	14	875	8020	.8020
1	8	1 000	7/8	875	1	14	1 000	.9274	9274
1 1/8	7	1.125	63/64	9843	1 1/8	12	1 125	1 3/64	1.0468
1 1/4	7	1 250	1 7/64	1 1093	1 1/4	12	1 250	1 11/64	1.1718

TABLE 12. — AMERICAN NATIONAL SPECIAL SCREW THREAD PITCHES (N.S.) AND RECOMMENDED TAP DRILL SIZES

Sizes	Threads per inch	Outside diameter of screw	Tap drill sizes	Decimal equivalent of drill
1/4	24	250	4	2090
	27		3	2130
	32		7/32	.2187
5/16	20	3125	17/64	2656
	27		J	.2770
	32		9/32	2812
3/8	20	375	21/64	3281
	27		R	.3390
7/16	24	4375	X	.3970
	27		Y	4040
1/2	12	.500	27/64	4219
	24		29/64	4531
	27		15/32	.4687
9/16	27	5625	17/32	5312
5/8	12	625	35/64	5469
	27		19/32	5937
3/4	12	750	43/64	6719
	27		23/32	7187
7/8	12	875	51/64	7969
	18		53/64	8281
	27		27/32	8437
1	12	1 000	59/64	9219
	27		31/32	9687

TABLE 13. — BASIC THREAD DIMENSIONS, TAP AND CLEARANCE DRILL SIZES

Machine Screw Sizes — National Form

Nominal Size	Major Diameter	Tap Drill Number	Clearance Drill Number	Decimal Equivalent of Tap Drill	Decimal Equivalent of Clearance Drill
0 80	.0600	56	48	.0469	.0760
1-56	.0730	54	45	.0550	.0820
-64	.0730	53	45	.0595	.0820
-72	.0730	53	45	.0595	0820
2-56	.0860	50	42	.0700	.0930
64	.0860	50	42	.0700	.0930
3-48	.0990	47	37	.0785	.1040
-56	0990	45	38	.0820	.1040
4 32	.1120	45	32	.0820	.1160
-36	.1120	44	31	.0860	.1200
-40	.1120	43	31	.0890	.1200
-48	.1120	42	30	.0935	.1280
5 36	.1250	40	30	.0980	.1280
-40	.1250	38	29	.1015	.1360
-44	.1250	37	29	.1040	.1360
6-32	.1380	35	28	.1100	.1400
36	.1380	34	28	.1110	.1400
-40	.1380	33	28	.1130	.1400
7-30	.1510	31	22	.1200	.1570
32	.1510	31	22	.1200	.1570
-36	.1510	30	22	.1280	.1570
8-30	.1640	30	18	.1285	.1690
-32	.1640	29	18	.1360	.1690
-36	.1640	29	18	.1360	.1690
-40	.1640	28	18	.1405	.1690
9-24	.1770	29	13	.1360	.1850
-30	.1770	27	13	.1440	.1850
-32	.1770	26	13	.1470	.1850
10-24	.1900	25	9	.1495	.1960
-28	.1900	23	9	.1540	.1960
-30	.1900	22	9	.1570	.1960
-32	.1900	21	9	.1590	.1960
12-24	.2160	16	1	.1770	.2280
-28	.2160	14	1	.1820	.2280
-32	.2160	13	1	.1850	.2280
14-20	.2420	10	¼	.1935	.2500
-24	.2420	7	¼	.2010	.2500
16-18	.2680	3	$\frac{9}{32}$	.2130	.2810
-20	.2680	3	$\frac{9}{32}$	.2130	.2810
-22	.2680	2	$\frac{9}{32}$	.2130	.2810

TABLE 13 (continued)

Fractional Sizes — National Form

Nominal Size	Major Diameter	Tap Drill Number	Clearance Drill Number	Decimal Equivalent of Tap Drill	Decimal Equivalent of Clearance Drill
1/16–64	.0625	3/64	50	.0469	.0700
–72	.0625	3/64	50	.0469	.0700
5/64–60	.0781	1/16	44	.0625	.0860
–72	.0781	52	44	.0635	.0860
3/32–48	.0938	49	38	.0730	.1010
–50	.0938	49	38	.0730	.1010
7/64–48	.1094	43	31	.0890	.1200
1/8 –32	.1250	3/32	29	.0937	.1360
–40	.1250	38	29	.1015	.1360
9/64–40	.1406	32	25	.1160	.1490
5/32–32	.1563	1/8	19	.1250	.1660
–36	.1563	30	19	.1285	.1660
11/64–32	.1719	9/64	14	.1408	.1820
3/16–24	.1875	26	9	.1470	.1960
–32	.1875	22	9	.1570	.1960
13/64–24	.2031	20	3	.1610	.2190
7/32–24	.2188	16	1	.1770	.2280
–32	.2188	12	1	.1890	.2280
15/64–24	.2344	10	1/4	.1935	.2500
1/4–20	.2500	7	17/64	.2010	.2650
–24	.2500	4	17/64	.2090	.2650
5/16–18	.3125	17/64	21/64	.2656	.3281
–24	.3125	9/32	21/64	.2812	.3281
–32	.3125	19/64	21/64	.2968	.3281
3/8–16	.3750	5/16	25/64	.3125	.3906
–20	.3750	21/64	25/64	.3281	.3906
–24	.3750	21/64	25/64	.3281	.3906
7/16–14	.4375	3/8	29/64	.3750	.4531
–20	.4375	25/64	29/64	.3906	.4531
–24	.4375	25/64	29/64	.3906	.4531
1/2–12	.5000	27/64	33/64	.4218	.5156
–20	.5000	29/64	33/64	.4531	.5156
–24	.5000	29/64	33/64	.4531	.5156
9/16–12	.5625	31/64	37/64	.4843	.5781
–18	.5625	33/64	37/64	.5156	.5781
5/8–11	.6250	17/32	41/64	.5312	.6406
–12	.6250	35/64	41/64	.5468	.6406
–18	.6250	37/64	41/64	.5781	.6406
11/16–11	.6875	19/32	45/64	.5937	.7031
–16	.6875	5/8	45/64	.6250	.7031
3/4–10	.7500	21/32	49/64	.6562	.7656
–12	.7500	43/64	49/64	.6781	.7656

TABLE 14. — DECIMAL EQUIVALENT OF DRILLS NO. 1 TO 60

Drill No.	Decimal	Drill No.	Decimal
1	.228	31	.120
2	.221	32	.116
3	.213	33	.113
4	.209	34	.111
5	.205	35	.110
6	.204	36	.106
7	.201	37	.104
8	.199	38	.101
9	.196	39	.099
10	.193	40	.098
11	.191	41	.096
12	.189	42	.093
13	.185	43	.089
14	.182	44	.086
15	.180	45	.082
16	.177	46	.081
17	.173	47	.078
18	.169	48	.076
19	.166	49	.073
20	.161	50	.070
21	.159	51	.067
22	.157	52	.063
23	.154	53	.059
24	.152	54	.055
25	.149	55	.052
26	.147	56	.046
27	.144	57	.043
28	.140	58	.042
29	.136	59	.041
30	.128	60	.040

TABLE 15. — DECIMAL EQUIVALENT OF FRACTIONAL DRILLS $\frac{1}{64}$ TO 1 INCH

Drill Size	Decimal	Drill Size	Decimal
1/64	.0156	33/64	.5156
1/32	.0312	17/32	.5312
3/64	.0468	35/64	.5468
1/16	.0625	9/16	.5625
5/64	.0781	37/64	.5781
3/32	.0937	19/32	.5937
7/64	.1093	39/64	.6093
1/8	.1250	5/8	.6250
9/64	.1406	41/64	.6406
5/32	.1562	21/32	.6562
11/64	.1718	43/64	.6718
3/16	.1875	11/16	.6875
13/64	.2031	45/64	.7031
7/32	.2187	23/32	.7187
15/64	.2343	47/64	.7343
1/4	.2500	3/4	.7500
17/64	.2656	49/64	.7656
9/32	.2812	25/32	.7812
19/64	.2968	51/64	.7968
5/16	.3125	13/16	.8125
21/64	.3281	53/64	.8281
11/32	.3437	27/32	.8437
23/64	.3593	55/64	.8593
3/8	.3750	7/8	.8750
25/64	.3906	57/64	.8906
13/32	.4062	29/32	.9062
27/64	.4218	59/64	.9218
7/16	.4375	15/16	.9375
29/64	.4531	61/64	.9531
15/32	.4687	31/32	.9687
31/64	.4843	63/64	.9843
1/2	.5000	1	1.0000

TABLE 16.—SUGGESTED SPEED AND FEED FOR HIGH-SPEED STEEL DRILLS

Diameter of drill (inches)	Revolutions per minute											Feed per revolution (inches)
	Aluminum	Brass	Cast iron[1]	Mild steel 20–30 carbon	Steel 40–.50 carbon	Tool steel 1 20 carbon and drop forgings	Conn. rod molybdenum steel	3 50 nickel steel	Stainless steel and monel metal	Malleable iron	Slate	
	300 feet	200 feet	100 feet	110 feet	80 feet	60 feet	55 feet	65 feet	50 feet	85 feet	15 feet	
1/16	18,336	12,224	6,112	6,724	4,883	3,668	3,404	3,976	3,056	5,192	916	.0015
1/8	9,168	6,112	3,056	3,362	2,444	1,834	1,702	1,988	1,528	2,596	458	002–003
3/16	6,108	4,072	2,036	2,242	1,630	1,222	1,120	1,324	1,018	1,734	306	.004
1/4	4,584	3,056	1,528	1,681	1,222	917	851	994	764	1,298	229	005
5/16	3,666	2,444	1,222	1,344	978	733	672	794	611	1,039	184	.005
3/8	3,054	2,036	1,018	1,121	815	611	560	662	509	867	153	006
7/16	2,622	1,748	874	921	699	524	481	568	437	742	131	007
1/2	2,292	1,528	764	840	611	459	420	497	382	649	115	.008
9/16	2,037	1,358	679	747	543	407	373	441	340	577	102	.008
5/8	1,836	1,224	612	673	489	367	337	398	306	520	92	009
11/16	1,665	1,110	555	611	444	333	300	360	273	472	84	.009
3/4	1,524	1,016	508	559	408	306	279	330	254	433	77	.010
13/16	1,422	948	474	521	379	284	261	308	237	403	71	010
7/8	1,314	876	438	482	349	262	241	285	219	371	66	011
15/16	1,221	814	407	448	326	244	224	265	204	346	61	.012
1	1,146	764	382	420	306	229	210	258	191	325	58	013
1 1/16	1,077	718	359	395	287	215	197	233	180	305	54	.013
1 1/8	1,020	680	340	374	272	204	187	221	170	288	51	014
1 3/16	966	644	322	354	258	193	177	209	161	274	48	014
1 1/4	918	612	306	337	245	183	168	199	153	260	46	.015
1 5/16	873	582	291	320	233	175	160	189	146	248	44	015
1 3/8	834	556	278	306	222	167	153	180	139	236	42	.015
1 7/16	795	530	265	292	212	159	146	172	133	225	40	.015
1 1/2	762	508	254	279	204	153	140	165	127	216	38	015
1 9/16	732	488	244	268	195	146	134	159	122	207	37	016
1 5/8	702	468	234	257	188	141	129	152	117	201	35	.016
1 11/16	678	452	226	249	181	136	124	147	113	192	34	.016
1 3/4	654	436	218	240	175	131	120	142	109	186	33	.016
1 13/16	630	420	210	231	168	126	116	137	105	179	32	016
1 7/8	612	408	204	224	163	122	112	133	102	173	31	.016
1 15/16	591	394	197	216	158	118	108	128	99	168	30	.016
2	573	382	191	210	153	115	105	124	96	162	29	.016

[1] Soft grade 50 per cent faster.

TABLE 17. — DECIMAL EQUIVALENT OF THREE SYSTEMS OF DRILL SIZES

Size	Decimal Equivalent	Size	Decimal Equivalent	Size	Decimal Equivalent
1/2	.500	7/32	.2187	40	.098
31/64	.4843	3	.213	41	.096
15/32	.4678	4	.209	3/32	.0937
29/64	.4531	5	.2055	42	.0935
7/16	.4375	6	.204	43	.089
27/64	.4218	13/64	.2031	44	.086
Z	.413	7	.201	45	.082
13/32	.4062	8	.199	46	.081
Y	.404	9	.196	47	.0785
X	.397	10	.1935	5/64	.0781
25/64	.3906	11	.191	48	.076
W	.386	12	.189	49	.073
V	.377	3/16	.1875	50	.070
3/8	.375	13	.185	51	.067
U	.368	14	.182	52	.0635
23/64	.3594	15	.180	1/16	.0625
T	.358	16	.177	53	.0595
S	.348	17	.173	54	.055
11/32	.3437	11/64	.1718	55	.052
R	.339	18	.1695	56	.0465
Q	.332	19	.166	57	.043
21/64	.3281	20	.161	58	.042
P	.323	21	.159	59	.041
O	.316	22	.157	60	.040
5/16	.3125	5/32	.1562	61	.039
N	.302	23	.154	62	.038
19/64	.2968	24	.152	63	.037
M	.295	25	.1495	64	.036
L	.290	26	.147	65	.035
9/32	.2812	27	.144	66	.033
K	.281	9/64	.1406	67	.0313
J	.277	28	.1405	68	.031
I	.272	29	.136	69	.029
H	.266	30	.1285	70	.028
17/64	.2656	1/8	.125	71	.026
G	.261	31	.120	72	.025
F	.257	32	.116	73	.024
E-1/4	.250	33	.113	74	.0225
D	.246	34	.111	75	.021
C	.242	35	.110	76	.020
B	.238	7/64	.1093	77	.018
15/64	.2343	36	.1065	78	.0156
A	.234	37	.104	79	.0145
1	.228	38	.1015	80	.0135
2	.221	39	.0995		

TABLE 18. — BIT OR DRILL SIZES

No of Screw	For Shank Clearance Holes		For Pilot Holes								No of Auger Bit to counterbore for sinking head (by 16ths) Slotted&Phillips
			Hard Woods				Soft Woods				
	Twist Bit (Nearest size in fractions of an inch) Slotted & Phillips	Drill Gage No or Letter To be used for maximum holding power Slotted & Phillips	Twist Bit (Nearest size in fractions of an inch) Slotted	Twist Bit (Nearest size in fractions of an inch) Phillips	Drill Gage No To be used for maximum holding power Slotted	Drill Gage No To be used for maximum holding power Phillips	Twist Bit (Nearest size in fractions of an inch) Slotted	Twist Bit (Nearest size in fractions of an inch) Phillips	Drill Gage No To be used for maximum holding power Slotted	Drill Gage No To be used for maximum holding power Phillips	
0	1/16	52	1/32		70		1/64		75		
1	5/64	47	1/32		66		1/32		71		
2	3/32	42	3/64	1/32	56	70	1/32	1/64	65	75	3
3	7/64	37	1/16	1/32	54	66	3/64	1/32	58	71	4
4	7/64	32	1/16	3/64	52	56	3/64	1/32	55	65	4
5	1/8	30	5/64	1/16	49	54	1/16	3/64	53	58	4
6	9/64	27	5/64	1/16	47	52	1/16	3/64	52	55	5
7	5/32	22	3/32	5/64	44	49	1/16	3/64	51	53	5
8	11/64	18	3/32	5/64	40	47	5/64	1/16	48	52	6
9	3/16	14	7/64	3/32	37	44	5/64	1/16	45	51	6
10	3/16	10	7/64	3/32	33	40	3/32	5/64	43	48	6
11	13/64	4	1/8	7/64	31	37	3/32	5/64	40	45	7
12	7/32	2	1/8	7/64	30	33	7/64	3/32	38	43	7
14	1/4	D	9/64	1/8	25	31	7/64	3/32	32	40	8
16	17/64	I	5/32	1/8	18	30	9/64	7/64	29	38	9
18	19/64	N	3/16	9/64	13	25	9/64	7/64	26	32	10
20	21/64	P	13/64	5/32	4	18	11/64	9/64	19	29	11
24	3/8	V	7/32	3/16	1	13	3/16	9/64	15	26	12

TABLE 19. — SPECIFICATIONS FOR SOME COMMONLY USED METAL FORMS

Metal & Form	Thickness (Gage)	Widths	Lengths
Sheet steel	U. S. Standard Steel Gage 12 to 28	24"-30"	72"–144"
Sheet copper	Brown and Sharpe American Standard Wire & others, also by weight; 16 oz. per square foot	24"–60"	60"–144"
Sheet brass	B. & S. also by 64ths of an inch; 3/64" to 8/64"	12"–24"	72"
Sheet aluminum	B.& S. 8 to 20 foil 0.00025"	varied	varied
Tin plate	U. S. St. Steel 33–25	10" × 14" 14" × 20" 20" × 28"	
Steel plate	3/16"–10"	7' -120"	varied
Bands, steel	1/16–1/4"	1/2"–4"	varied
Round bars, steel	1/16"–6" Dia.		20 feet
Square bars, steel	1/4"–6"		20 feet
Flat bars, steel	3/8"-6"	1/4"–3"	20 feet
Flat bars, copper	1/8"–1/2"	1/4"–4"	varied
Wire, steel	B. & S. 0000–36 also U. S. Wire		
Wire, copper	B. & S. 12–22		

TABLE 20. — ENGLISH WIRE GAGES

Gage No.	Decimal Inch Equivalent	Approximate Fractional Inch Equivalent	Approximate Millimeter Equivalent
1	.300	19/64	7.62 mm.
2	.284	9/32	7.21 mm.
3	.259	17/64	6.58 mm.
4	.238	15/64	6.05 mm.
5	.220	7/32	5.59 mm.
6	.203	13/64	5.16 mm.
7	.180	3/16	4.57 mm.
8	.165	11/64	4.19 mm.
9	.148	5/32	3.76 mm.
10	.134	9/64	3.40 mm.
11	.120	1/8	3.05 mm.
12	.109	7/64	2.77 mm.
13	.095	3/32	2.41 mm.
14	.083	21/256	2.11 mm.
15	.072	9/128	1.83 mm.
16	.065	1/16	1.65 mm.
17	.058	7/128	1.47 mm.
18	.049	3/64	1.24 mm.
19	.042	5/128	1.07 mm.
20	.035	9/256	.89 mm.
21	.032	1/32	.81 mm.

TABLE 21. — MELTING POINTS OF METALS AND SOLDERS

Metals	Degrees Fahrenheit	Degrees Centigrade
Aluminum	1216	658
Antimony	1166	630
Bismuth	518	270
Copper	1981	1083
Gold	1945	1063
Lead	621	327
Silver	1762	961
Tin	450	232
Zinc	786	419

TABLE 22.—ALLOYS OF SOLDER

(Melting points only approximate
Tin content mentioned first)

Alloys	Degrees Fahrenheit	Degrees Centigrade
25/75	500	260
30/70	480	249
35/65	470	243
40/60	460	238
45/55	440	227
50/50	415	213
55/45	390	199
60/40	370	188
63/37	358	181

TABLE 23.—MANILA ROPE SPECIFICATIONS

Size (Diameter in Inches)	Breaking Strength, New Rope (lbs.)	Safe Working Strength, New Rope (lbs.)	Weight of Rope (lbs. per ft.)
¼	700	200	.02
⅜	1,450	400	.0417
½	2,450	700	.075
⅝	4,000	1100	.133
¾	4,900	1400	.165
1	8,200	2300	.27
1¼	12,500	3000	.42
1½	17,500	5000	.6

TABLE 24. — ROPE-LASHING SPECIFICATIONS

Size of Block		Size of Rope Lashings Required Number of Turns through Hooks of Blocks for the Following Sizes of Rope			
		$\frac{3}{8}''$	$\frac{1}{2}''$	$\frac{5}{8}''$ or $\frac{3}{4}''$	1″
3 inch	1 sheave	2			
3 inch	2 sheave	3	2		
3 inch	3 sheave	4	3		
4 inch	3 sheave		4	3	
6 inch	3 sheave			4	3
8 inch	3 sheave				4
6 inch	Snatch			4	3
8 inch	Snatch				4

TABLE 25. — STANDARD BLOCK SPECIFICATIONS

Size of blocks	Number of sheaves	Working strength of hooks (lbs.) *	Size of rope **	Suggested length (ft.)	Maximum load that may be applied to new small rope	Maximum load that may be applied to new large rope
3 inch	1	2,100	$\frac{3}{8}$ or $\frac{1}{2}$	50	400	700
3 inch	2	2,300	$\frac{3}{8}$ or $\frac{1}{2}$	75	400	600
3 inch	3	3,900	$\frac{3}{8}$ or $\frac{1}{2}$	100	400	650
4 inch	3	4 600	$\frac{1}{2}$ or $\frac{5}{8}$	150	700	800
6 inch	3	8,600	$\frac{3}{4}$	200	1400	
8 inch	3	12 000	1	275	2300	

* Maximum load permitted on hooks

** The smaller size rope should be used, in general, where the weather conditions are humid

B

Glossary

Adjustable die: A kind of die, for cutting external threads on a rod or bolt blank, which can be adjusted to make threads of different sizes.

Adjustment screw: The screw at one side of a divider by means of which fine adjustments can be made between the points.

Alloy steels: Steel combined with tungsten, vanadium, nickel, chromium, or other metals.

Alternate set: The set of teeth in a saw in which every other tooth is bent slightly to one side, and the others are bent slightly to the other side.

American Standard gage: A disc-shaped gage with various sizes of holes cut around the edges, used to measure copper wire.

Angiosperms: A great group of plants, such as grasses, roses, and most trees, which produce flowers. Angiosperm trees are known as deciduous trees. They produce the hardwoods.

Annealed gray iron: Iron made by heating gray-iron castings in an open muffle. It is more practical than malleable iron.

Annealing: Subjecting substances such as metals to high heat, to reduce brittleness or increase toughness.

Annual rings: The concentric circles of small cells or fibers in the trunk of a tree. A new outer circle is added each year.

Ashton process: A chemical process which produces the same results as puddling, that is, heating and stirring.

Auger (ŏ′gẽr) **bit:** A bit with one of several kinds of cutting edge or blade.

Bands: The name for narrow, heavy strips of steel plate.

Bark: The protective outer coat of a tree, covering the layer of cell tissue called cambium.

Base: The material used with the pigment in paints; may be white lead or zinc.

Bast: The inner part of tree bark.

Bastard-cut file: A file with rather coarse teeth for heavy work.

Beam: In a marking gage, the main arm of the gage, with the markings inscribed on it.

Becket: The immovable part at the bottom of a pulley to which one end of a rope is attached.

Bench stop: A dog set in a holder for holding a piece of wood to be planed or sandpapered; used for wood which is not of the size or shape to be held in a vise.

Bevel: An inclined surface other than 90 degrees between opposite sides of a board; also a tool with two jointed rules, for drawing angles or adjusting surfaces to a given inclination.

Bight: The bend formed in rope when the end and the "standing part" are parallel to each other.

Birmingham and Stubbs gage: A gage used to measure iron wire.

Bit brace: A tool used to hold the bit or drill firm, by means of a square, tapered tang, when a hole is being drilled.

Bit gage: A gage consisting of a single piece of metal with one end bent at a right angle and flattened, and the other equipped to clamp it to the shank of a countersink. It is used when several holes are countersunk to the same depth.

Blank: A file before it has been cut.

Blind hole: A hole that is bored only part way through the material.

Block: One or more sheaves (grooved wheels) held in a frame.

Block becket bend: A kind of knot used to attach a loop of rope to the eye of a guy rod or the becket of a pulley.

Block plane: A plane with its blade set so as to meet the wood at a lower angle than a smooth plane does; used on the end grain of wood.

Blueprint: A photographic print of a detail drawing; it is white on a blue background.

Board: Any piece of lumber measuring up to 1½ inches thick.

Board foot: A piece of wood one foot square and one inch thick, the unit by which lumber is bought and sold.

Bolt: An iron or steel rod, parallel throughout its length, with a head at one end and a thread cut part way along the length at the other end.

Bow divider: A small compass, one leg of which carries a pencil, pen, or point; in many the legs are connected by a bow-shaped spring instead of a joint.

Bowline knot: One of the common types of knots for fastening a line upon itself or around another object.

Brace table: An additional marking consisting of a group of numbers on some framing squares. A single number gives the diagonal measure or length of a brace, when placed against other numbers at right angles at the distances indicated by two other numbers.

Brad: A thin, small nail with only a slight projection instead of a head.

Braze: To solder with hard solder or brass.

Brazier-head rivet: A rivet used on certain external surfaces of aircraft and for patching.

Breaking strain: The amount of pull, stretch, or strain a rope will stand before it will separate or break.

Brush-keeper: A container in which paint or varnish brushes are kept suspended in liquid. The kind of liquid depends on the kind of paint or varnish used.

Burnisher: A narrow tool with a hard, smooth, rounded end or surface, for smoothing, polishing, or turning over an edge.

Bus bar: A round or square wire that makes a strong and rigid conductor for electricity.

Bushing: A sleeve or liner inserted between the center opening of a sheave and the shaft on which it revolves, to keep the softer part from wearing.

Butt joint: In woodworking, a joint formed by fastening together two pieces of wood without fitting one piece into the other.

Butt joint: In wiring, a joint made by fastening two wires together face to face, joining them with solder.

Cabinet file: A thin, half-round file tapering from the middle to the point, used in cabinet work.

Cable (or Cable-laid): A rope consisting of three ropes laid together to form a rope of larger diameter.

Calibrated (kăl′ĭ-brāt′ĕd): Showing graduations or capacity, as by division marks on a scale.

Caliper rule: A type of folding rule which has in addition a brass caliper slide graduated in fractions of an inch.

Cambium: A layer of cell tissue between the sapwood and inner bark of a tree.

Cape chisel: A chisel used for cutting rectangular grooves.

Carbon-steel drill: A cheap drill, for ordinary work, which will lose temper or soften if used at a high speed.

Carriage bolt: A bolt with a square section under the head which is forced into the wood so the bolt will not turn as the nut is tightened.

Castings: The metal objects formed by pouring molten metal into molds.

C-clamp: A clamp with a C-shaped frame, used to hold two pieces of wood together temporarily.

Cementite: A hard, brittle iron carbide in the form of reinforcing sheets; these sheets crisscross through a honeycomb of pure iron, in steel, cast iron, and most iron-and-carbon alloys.

Center punching: When holes are to be drilled in metal, a punch is first tapped by a hammer against the spot; the mark then guides the drill point

Chalking: The rubbing of chalk on a file, before it is used on soft metals, to prevent it from becoming clogged

Chamfer (chăm′fĕr) The surface formed by cutting away the angle made by two faces of a piece of timber

Check nut: A type of nut used with plain nuts and set screws to prevent them from coming loose and dropping off

Checks: Lengthwise separations of wood, usually across the annual rings, caused by improper seasoning

Cheeks (of a hammer) The sides of the head of a hammer

Chiseled brush: A paint brush with chisel-shaped bristle end, used for applying enamel, varnish, shellac, and lacquer

Choking: The filling up of a hole with chips which are not forced free of the hole when a drill is being used

Chuck: A holding part on a machine In a hand drill, the drill part is fastened into the chuck at a point past the cutting spiral

Clamp lugs: Lugs resembling cup lugs except that they have clamps to fasten the lug projection to the wire

Clamping screw: The screw which clamps the handle and movable blade of a T-bevel together, it may be loosened to move the blade or tightened to set it

Claw (of hammer) A curved notched prong opposite the face on a hammer's head, it is used to extract nails

Clinching: Bending over the projecting point of a nail, it should be done across the grain and with the head against a holding metal surface

Clove hitch: One type of knot used for securing a line to a ring or spar, or to pass it over low objects

Coil of rope: A many-layered ring of rope wound spirally

Coir rope: A rough, red rope from the spongy covering of coconuts; it has poor wearing qualities

Cold chisel: A flat chisel used for chipping and for shearing off metal held in a vise

Collapse: A defective condition in which a single cell or row of cells in the heartwood of a log becomes flattened It is caused by improper seasoning

Compass saw: A saw with a sharp-pointed, tapering blade used to cut circles or curves

Conductor: Most often, a wire for carrying an electric current.

Conifer: The general class of trees known as softwoods

Contline: The groove between the strands of a rope along which a cord may be laid during splicing

Coping (kōp′ĭng) **saw** (also called a kitchen saw): A saw resembling a hacksaw: it has its blade stretched in a frame.

Cordage: All sizes of rope are spoken of as cordage: those smaller in circumference than 1¾ inch are not referred to as rope, but have other names such as small cordage or twine.

Cortex: The outer part of tree bark.

Cotter pin: A split pin used for keeping the sheave pin (shaft on which the sheaves roll) of a block from slipping out of the block frame: also a wedge-shaped piece of wood or metal driven into a tapered opening.

Counterboring: Boring of a hole larger than the diameter of the screwhead, when it must be set below the surface of the wood.

Countersink: A cone-shaped cutter used to cut a depression so that a flathead screw can be set flush or below the surface.

Countersinking: Shaping a hole or depression to the shape and thickness of a screwhead, so that the head can be set flush with, or below, the surface of the wood.

Coupling nut: A nut used in electrical work to join two protective conduits or to join one of them to a junction box.

Crosscut saw: A saw with a rake angle of 75 degrees, used to cut across the grain.

Cross-lap joint: A joint formed when two pieces of wood cross one another so that the surfaces are flush.

Crown splice: A kind of knot made in the end of rope to keep it from unlaying. It makes whipping of the end unnecessary.

Cup lug: A cup-shaped projection by which something is supported: cables and wires may be sweated into terminal cup lugs to attach them.

Cut splice: A splice used where two ropes are joined so that they have a loop or eye at the place of joining.

Dado joint: A joint formed by cutting a recess across the grain of a piece of wood from edge to edge or face to face to receive a second piece: it has two shoulders or vertical cuts, whereas a rabbet joint has one.

Dead smooth (applied to files): Having very fine teeth used for special work.

Deciduous trees: Trees which lose their leaves during the fall and winter and burst into foliage in the spring. They furnish the hardwoods. Such trees belong to the great group of plants called Angiosperms.

Depth of thread: The distance between the crest and root of a screw thread measured perpendicular to the axis.

Diagonals: A kind of pliers used only for cutting wire.

Die: A tool, threaded like a nut, which cuts external threads on a rod or bolt blank.

Dimensioning: The showing of distances between points as in a detail drawing for draftsmen.

Direct tension: A strain or pull applied directly to an object. Nails are said to be under direct tension if they are driven so that they are parallel to the pull of the wood itself, as in drawers to be pulled out. (They should not be so driven.)

Divider: A two-legged instrument which cuts or scribes lines into a surface. It differs from a compass which only marks the lines on the surface.

Dog: A holding device — such as a rectangular piece of steel set in the recess in the jaw of a woodworker's vise — used as a stop for a piece of wood.

Double-beveled tool: A blade which has both sides sloping to form the cutting edge, as with most knives.

Double-cut file: A file with one set of teeth crisscrossing over another set.

Dowel: A cylinder of wood used to reinforce butt joints.

Drag bar: The part of a vise which keeps the guide rods parallel and prevents binding.

Drawing: A reheating process by which carbon steel which has been hardened can be softened slightly; this is done in making hammer heads.

Drill: A rotating tool with cutting edges at the point; it cuts holes into or through metal or wood.

Drill press: A power drill that can be used only when the work is brought to the machine.

Eccentric (ĕk-sĕn′trĭk)**:** Off center, the pointed inserts in a divider may have the point eccentric, or not in the same center, as the axis, so that fine adjustments can be made by loosening the clamping screw and rotating the point.

Edge grain: The surface of softwood when sawed crosswise.

Electrician's knife: A knife with a frame, screwdriver blade, and cutting blade.

End: The end, or "running part," is the short free end of a rope which is usually handled most in making knots.

Equaling file: A blunt, almost parallel-edged, but slightly bulging, rectangular file.

Escutcheon (ĕs-kŭch′ŭn)**:** A metal shield used as a protector, such as the shield through which an electric-light switch is set.

Essex board measure scale: A scale marked on the body of a framing square which determines the number of board feet in a piece of wood without calculations.

Explosive rivets: Rivets used for places where only one side can be reached; a charge inserted in the end explodes when the rivet is held in place and swells it out.

Eye of hammer: The part of the metal head of a hammer through which the small end of the handle passes.

Eye splice: A permanent loop or eye made in the end of a rope by splicing the end into a near part of the rope proper.

Face (of hammer): The surface of the hammer head which strikes against the nail or other object to be pounded.

Faceplate: A piece of metal set into the movable head of a marking gage to prevent excessive wear.

Feed pressure: The rate, involving speed and pressure, at which a drill moves into the stock being drilled.

Feed screw: Any threaded screw that is used to aid the feeding or driving of a tool. The screw or spur on an auger bit helps to drive the bit into the wood; the threaded portion pulls itself and the rest of the bit into the wood.

Fence: An attachment to a plane, saw bench, or woodworking machine, which controls the extent or location of the cut.

Ferrite: A honeycomb structure of pure iron which binds together the structure in cast iron.

Ferule (fĕr'ĭl): A metal covering on the part of a knife handle where it joins the blade, or a similar part on other tools, as on a brad awl handle. It keeps the handle from splitting.

Fid: A tool used like a marlinspike to separate the strands of rope: it is larger than a marlinspike and made of hardwood instead of steel.

Field-wire T-splice: An electrical splice used to tap a permanently installed line without interrupting the service.

Figure-eight knot: A knot resembling the figure 8 and most often used at the end of a rope to prevent it from slipping through a pulley.

File card: A kind of brush with wire on one side and bristles on the other, used to clean a clogged file.

Flat file: The most common shape in files; it comes in a variety of cuts and coarseness.

Flexible-steel-tape rule: A rule designed to close up so as to be compact in size.

Flute: The grooved part in the spiral of a bit or drill; it carries the chips to the top of the hole and prevents choking.

Flux: A substance such as rosin which keeps out oxygen from wires to be soldered together.

Foerstner (fûrst′nẽr) **bit:** A spurless, wood-drilling bit with two scoring ribs; similar to the auger bit and expansive bit.

Ford decimal scale: A system of measuring by which an inch is divided into tenths.

Frame pins: In a hacksaw these are pins inserted through holes in the end of the blade, so that the blade can be mounted.

Gage line: The marked line along which an edge is cut.

Gain: A notch or groove in wood.

Galvanizing: The process of dipping steel sheets into melted zinc to give them a rustless coating.

Gimlet (gĭm′lĕt) **bit:** Is used to bore small holes for screws and nails; it has a cross handle.

Glue joints: Joints held with glue; they are not satisfactory for end-to-end or end-to-edge pieces.

Guide rods: Rods that keep the jaws of a woodworker's vise parallel at all times.

Guy rope: A rope used for steadying or bracing objects.

Gymnosperms: A great group of plants, such as the pine, which bear cones. Gymnosperm trees are commonly known as conifers or evergreens. They produce the softwoods.

Half-hitch: A turn of rope so arranged that a section of the turn will bear, or press, on another section of it.

Hand miller: A small, light type of milling machine in which the operator moves the table by a lever.

Handscrew: The clamp, with two jaws and two spindles, used to hold material tightly to a bench top.

Hawser: Any rope 5 inches or more in circumference.

Head: In a marking gage, the movable part which can be moved along the beam or marker, and tightened at any division.

Heartwood: The center wood of a tree, through which the cells no longer conduct sap.

Hemp: A fiber from any one of many plants, used to make rope. Fibers from the hemp plant are the most commonly used.

Hexagonal nuts: These six-sided nuts are usually used on screws.

Hitch: To attach a rope to another object in such a way that it can be readily detached.

"Hogging in": Process occurring when a twist drill screws itself into the material of soft metals: it may break the drill.

Hone: A stone of fine grit used for sharpening blades; a whetstone or oilstone.

Honeycombing: A form of defective separation in wood which usually occurs in the interior and follows the medullary rays. It is caused by improper seasoning.

Hook: The curved or bent piece by which a block is held in place, or to which the weight to be moved is attached.

Idler pinion: A small gear below the handle on some hand drills. It equalizes the thrust of the large driving gear.

Insulator: Nonconducting material such as the material which covers an electric wire.

Internal micrometer: A micrometer for making internal measurements.

Joint: In wiring, a joint is made by uniting two solid wires.

Knots: Various combinations of bights and loops so arranged that the tight part of the rope will bear on the free end; they make ropes hold.

Knurled (nûrld): Used to describe a nut with a beaded surface, by means of which a divider can be locked at a given setting.

Lap joint: The joint formed by one piece of stock extending over another, with a section of each removed, for fitting them together.

Lateral resistance (Sidewise resistance or pull): It occurs when nails are driven correctly, or at right angles to the direction of force — for instance, at right angles to the direction a drawer is pulled out.

Lathe (lāth): A machine tool in which the work is held and rotated about a horizontal axis while a cutting tool forms the work to shape and size.

Lay: The direction in which strands are twisted to form a rope.

Layer: A rope walk, where the required number of strands are laid or twisted to make rope.

Lead burning: A welding process by which lead, in lead pipes, etc., is shaped and joined.

Left-laid rope: A rope laid so that the strands slope from upper left to lower right when it is held up; also called left-handed rope.

Length (of a piece of wood): The measurement of wood from end to end, or with the grain.

Linear measure: A measure used for measuring along a straight line.

Lineman's pliers: Blunt-nosed pliers, also called "Side-cutting," with a scored gripping surface on the front ends: for gripping, wire splicing, and cutting.

Lips: The part of the cutting end of an auger bit which follows the spurs and cuts out the wood.

Lock-joint divider: A divider which can be locked at a given setting by the use of a knurled nut.

Lock screw: Also called machine screw, is one having the same diameter throughout the threaded portion. It secures a movable part in any particular place. (An example is the thumb screw in the head of a marking gage.)

Logging: The processes from felling a tree to delivering the logs to a sawmill.

Long-nosed pliers: One of the common types of pliers, with long, flat jaws.

Long straight splice: A splice which leaves the rope only a little thicker where spliced; it can be used in pulley work.

Loop bending: The bending of a wire into a loop, so that when the loop is bent around a screw an electrical connection can be made.

Loop joint: A joint of wire made by looping one wire over and around another, closing the loop with pliers and soldering it.

Low-temper steel: Steel that will lose its temper or hardness if exposed to great heat.

Luffing tackle: An extra set of tackle, or combination of ropes and blocks, used when a greater pull is required than can be exerted by one or even several men.

Lumber: The term applied to logs that have been milled and cut into boards, planks, timbers, and beams.

Machine screw: A kind of screw requiring a threaded hole, since it is used most often without a nut.

Machinist's file: Usually a double-cut file leaving a rough finish; used to remove metal quickly.

Mallet: A hammer-like wooden tool with two faces, used for driving wood.

Manila hemp: A very strong and durable hemp from the Philippine Islands. It comes from the abaca plant.

Marking gage (gāj): A measure used for drawing or scribing lines parallel to the edge or the face of a piece of wood: it consists of beam, head, thumbscrew, shoe, faceplate, pin, and stopscrew.

Marlinspike: A tapered iron tool for separating the strands of a rope in splicing.

Measure scale: See Essex board measure scale.

Medullary (mĕd'ŭ-lĕr'ĭ) **rays:** Rays radiating from the center of a tree; their function is storing food material and distributing it horizontally.

Micrometer (mī-krŏm'ĕ-tẽr): A measuring instrument based on the principle that a screw will advance a fixed amount when rotated in a nut; it can give an unlimited variation of measurements.

Middle-lap joint: A joint formed when the end of one piece of wood extends over to join the other at some point between the ends.

Mill file: A single-cut, square-edged file used for fine work, such as sharpening circular saws, and for lathe work.

Milling machine: A machine in which work is fastened to a heavy table and forced against a rotating cutter by the motion of the table.

Miter joint: A form of butt joint, with the joined pieces cut at any angle other than 90°.

Mortice (môrt′ĭs) **gage:** A type of gage with double pins on the same side of the beam, for scribing two parallel lines at one time.

Mortise-and-tenon joint: Consists of a mortise, or rectangular hole, cut into one part of a joint, and a tenon, or rectangular projection, the same size, cut on the end of the other piece of wood.

Muffle: A furnace in which the metal, or other substance to be heated, does not come in contact with the flame.

Nail set: A tool with a small tip used with a hammer to set nails and brads below the surface of wood.

Neck (of hammer): The part of a hammer ending in the hitting surface, or face.

Octagon scale: An additional marking of a framing square consisting of a series of dots on the tongue. It is used when laying out an octagon on a square.

Open muffle: An uncovered wrought-iron box in which castings are heated over a gas flame.

Orthographic (ôr′thȱ-grăf′ĭk) **projection:** A type of working drawing used by woodworkers. It shows the front, top, and side view of the object by lines projected perpendicular to the plane of projection.

Out of square: Having one edge or surface by accident slightly more or less than 90° from the adjoining one. A slanting edge or surface which occurs when the side lever of a plane is not properly adjusted, or if a plane is tilted from side to side.

Overhand knot: A knot made with an overhand loop, that is, with the standing part above the free end after it has crossed over.

Panel gage: A marking gage in which the beam, or main bar, is exceptionally long.

Parceling: The second step in a process to increase the wear of rope; it consists of winding a narrow strip of tarred canvas around the wormed rope, in the direction of the lay.

Paring chisel: A chisel used to shape a surface to be curved.

Paring gouge: A chisel with a curved edge, used to cut a curve.

Peen hammer: A hammer with a rounded end (or some other unusual shape of solid end) on the head opposite to the face; it may be used to set up tensions in metal, or produce dents and depressions.

Phillips head screwdriver: A screwdriver with a specially shaped tip cut so that it will fit the Phillips head screw, which has a four-way slot.

Pigment: The coloring material which is mixed with a base and with linseed oil or varnish to make paint.

Pilot hole: A small hole bored in the second of two pieces of wood to prepare it to receive the threaded end of a screw projecting through the first.

Pin: One or more pins are fastened into a marking gage to scribe lines on the material to be marked.

Pinning: A scratching of a surface which occurs when the file teeth are clogged with the material.

Pitch: On a bolt or screw, the number of threads to an inch, or the distance from a point on one thread to the same point on the adjacent thread.

Plain brace: One of the two types of bit brace, having no ratchet; it must be moved if handle is to be turned in the opposite direction.

Plain-edged files: Files with no teeth on the edges, used for work in corners and cramped places.

Planks: Lumber ranging in size from 1½ to 4½ inches thick.

Plate: One of the forms in which manufacturers supply metal to industry. Plate metal comes as tin plate or steel plate. The tin plate is steel covered with a protective coat of tin.

Plug cutter: A device for making a flush-set wood plug to conceal a screw set below the surface. It is used like a bit in a brace.

Poppet valve: A lift valve.

Power hacksaw: A power-driven hacksaw used for efficiency in preference to the hand type. It is used to cut up metals, bar stock, pipe, and so forth.

Puddle: Heavy iron bar used to stir melted metal when puddling.

Puddling: Converting pig iron to wrought iron by heating it and stirring it often in the presence of oxidizing substances. These free the iron of most of the carbon and other impurities.

Quartersawed: The surface cut in a hardwood log when sawed crosswise.

Rabbet (răb′ĕt): Channel, groove, or recess cut out of an edge or surface.

Rabbet joint: A joint formed by cutting a recess along the edge or end of one piece of wood, to receive the edge or end of another piece cut to fit.

Rafter table: A scale on the body of a framing square which indicates the length of a rafter for the more commonly used pitches such as $\frac{1}{6}$, $\frac{1}{4}$, and $\frac{1}{2}$.

Raker set: A way of setting the teeth of a hacksaw so that every third tooth remains straight, or unset.

Rasp: A tool like a file, but with its teeth formed separately, not cut in parallel rows.

Rasp-cut file: A very roughcut file with separated, individual teeth made by a chisel.

Ratchet (răch′ĕt) **brace:** A bit brace with a ratchet or pawl, which permits the user to turn the handle in the opposite direction without moving the bit.

Ream: To enlarge or clean out a hole that has been bored.

Reeving blocks: Passing ropes through the blocks of a tackle so that less pulling force can be used than the resistance of the object to be moved.

Rigging: The use of rope in various block-and-tackle combinations.

Right-laid: If the strands of a rope slope from upper right to lower left when it is held up, it is right-laid (or right-handed) rope.

Ripsaw: A saw used to cut with the grain.

Rivet: A headed pin of malleable metal; one type is put through the handle of a knife to hold the blade in place.

Rivetheader: A tool used to shape the head of a rivet.

Riv-Nut: A special type of rivet, for surfaces that can be reached on only one side.

Root: The part of a screw thread opposite the crest or top surface.

Root diameter: The minor diameter, or the smallest diameter of a bolt or a nut.

Rough-dry boards: Boards that have been seasoned but not dressed, or surfaced.

Round file: A file which, because of its round shape, is suitable for enlarging round holes and shaping curves.

Router: A plane used to finish the surface of any recess which requires a smooth surface.

Saddle: Two sections of wood joined at right angles. It can be held in a vise so that the partly open side is horizontal above the woodworker's table, and free to support small pieces of wood to be sawed.

Safe working strain: The *safe* working strain of rope, which considers the safety factor, and the fact that rope grows weaker with age and use; it is expressed in the formula: $\frac{C^2}{18} = \text{tons}$.

Sapwood: The lighter-colored wood, next to the heartwood; it has living cells and fibers that conduct food and water from the roots to the leaves.

Saw kerf (kûrf)**:** A section of the wood or other material removed by sawing.

Sawhorse: A rack on which wood is laid for sawing, or a trestle for the same purpose.

Scored gripping surface: A surface roughened by a series of grooves, so that it will grip better. The front end of the jaws of pliers have this kind of surface.

Scribe (skrīb)**:** To mark wood, metal, brick, etc., by cutting or scratching a line or lines with a pointed instrument.

Serving: The winding of a small cord closely around rope on top of the canvas parceling. It is the third and last step in the process to increase rope wear.

Serving splice (or whipping)**:** The winding of a small cord or twine closely around the end of a rope to keep it from fraying.

Set screw: A kind of screw used to hold wheels, knobs, or collars rigidly in place.

Shank: On a bit, it is the smooth length between the spiral and the tang; the length is determined by the depth of the hole the bit can make.

Shape filing: The name for the filing done when the round surfaces are filed with a rocking motion.

Shaper: A machine with a tool which peels off metal from a flat surface.

Sheave: The grooved wheel on which a rope rolls in a block; sometimes called the pulley.

Shoe: A small strip of metal placed between the head and beam on a marking gage, directly under the end of the thumb screw. The hole through which the beam passes is notched to take this strip.

Single-beveled tool: A tool with only one side sloping to form the cutting edge; for instance, the woodworker's chisel.

Single-cut file: A file with teeth slanting in only one direction.

Sisal (sī′săl) **rope:** A rope made from the fiber in the heavy leaves of a Mexican plant; it is about half as strong as manila rope.

Slipstone: An oilstone, for sharpening tools, shaped and used much like a file.

Sliver: A thin, continuous band which is spun or twisted to form the yarn of rope, later twisted into strands, and then laid to make the rope in its final form.

Slotting file: A file used for filing grooves for cotters, wedges, or keys.

Sloyd knife: A layout tool using a point which is held almost perpendicular to the surface while the lines are scribed.

Smooth file: A file with small teeth, used for fine work and finishing.

Soft solder: This commonly used solder is usually made chiefly of a half-and-half mixture of tin and lead.

Soldering copper (or iron): An iron rod with a copper head or tip and a wooden handle, used to apply the heat when soldering.

Solid shank rivets: The type of rivet commonly used for most sheet-metal work.

"Spaghetti": An insulating tubing of small diameter to be slipped over a bare electric wire.

Spelter: A type of hard solder consisting chiefly of four parts of metal to one part of zinc.

Spinning: An operation performed by means of a lathe, for making sheet metal into hollow objects.

Spiral: The series of spiral turns at the cutting end of a bit.

Splicing: The joining by interweaving of two separate pieces of rope, or of the end of rope to the main body.

Spoke shave: A tool in the form of a plane with a blade held in a frame, used to shape a curve. It differs from a chisel in that the blade is controlled.

Spurs: The parts of the cutting end of an auger bit which cut the fibers around the edge of the hole.

Square knot: A knot used when two ropes of the same size are united and will have to stand a strain.

Square nuts: Four-sided nuts generally used on bolts.

Squaring: Planing all the surfaces of rough stock to a finished size.

Square-trimmed brush: A paintbrush with square-shaped bristle ends for using paint that must be brushed on.

Steel scale: A scale of steel resembling the wooden ruler and using the same units. Finer lines can be scribed on it than on wood; it resists wear, and it can be tempered to any required flexibility.

Stock forms: A variety of forms of metal supplied in industry. These include sheet, plate, bar, wire, and band.

Stop screw: A screw like that placed near the end of a marking gage to prevent the head from flying off the beam.

Stove bolts: Bolts with heads slotted for a screwdriver, and requiring a clearance hole to be bored through both of the pieces of stock being joined.

Straightedge: A smooth iron edge used to test the evenness of a surface.

Strand (of rope): A number of yarns twisted together in the opposite direction to that of the threads of the yarn. Several strands are then twisted once again in the other direction.

Stretch-out: A pattern of heavy paper used in sheet-metal work; the intersections and lines are transferred easily by center punches made through the paper.

Surface plate: A plate usually made of specially aged cast iron, ground and scraped to be as flat as possible, for testing smoothness of a surface.

Swallow: The space between the hook end and the sheaves of a block. It may be grooved to give space to the rope.

Sweating: The process of holding together two or more wires or other electrical parts that have been coated with solder, and heating them until the solder melts and they become joined.

Sweep: The width of the arc made by the handle of a bit brace as it revolves.

Tang: The square, tapered end of an auger bit which holds the bit in the brace; or a similar extension of other tools, such as the part between the handle and blade of a knife.

Tap: A tool like a screw but with three or four evenly spaced grooves cut across the threads along the length. It avoids binding and friction, lets loosened metal come free, and allows for lubrication.

Tap splice: The splice made when a wire is taped onto a permanently installed wire after being wound around it.

Tapped: Having a screw thread cut on the inner surface — as the thread cut into one arm of the C-clamp frame — so that revolving the spindle can increase or decrease the space between the swivel head and the jaw.

Taut: A tight haul or rope under tension.

T-bevel: An instrument consisting of two rules jointed together and opening at any angle, for drawing angles.

Temper: The state of metal as to its hardness, toughness, etc.: it is dependent on the carbon content.

Terminal: In electrical apparatus, the connection made between the apparatus and the external wiring circuit.

Terminal punchings: Small electrical terminals; also terminals which have been stamped from a flat sheet of metal.

Thickness (of wood): The measurement of wood from face to face.

Thoroughfooting: A name applied to straightening out, unkinking, and then coiling, rope.

Thread: A spiral ride, uniform in size and shape, placed regularly on the outside or inside of a cylinder.

Threaded spindle: In a modern micrometer that part which rotates 1/25 of a revolution when the sleeve turns the distance of one division.

Thumbscrew: A screw like that at the top of the movable head of a marking gage, by which pressure is applied to secure the head at any point along the beam.

Toe-nailing: Process of driving a nail obliquely to avoid the splitting caused by driving directly into end grain.

Tool steel: A kind of steel with extra carbon content, suitable for making tools.

Trammel: Also called a beam compass, is used to draw or scribe circles too large to be made by a compass or dividers.

Trysquare: A right-angled measure for laying out stock, and for drawing lines at right angles to any given surface.

Twist bit: A bit which bores holes in wood for screws, nails, and bolts; it has a steeper cutting angle than the twist drill and is used on wood only.

Undulated set: The kind of set of hacksaw teeth in which small sections are bent in opposite directions, with gradual increase and decrease in degree of bend

Vernier calipers: A caliper rule with vernier adjustment and adjusting screw, for especially fine measurements.

Vise: A tool with two jaws closing by a screw, lever, or cam, for holding wood or other material to be worked.

Warp: To become twisted or bent out of a flat plane, as improperly seasoned lumber may do.

Washers: Metal discs used with screws, studs, and nuts to protect the surface of the metal, provide a larger clamping surface, or hold firmly.

Wheel dresser: A tool, with a set of star-shaped steel wheels in its end, used across the face of a wheel to remove grooves.

White iron: Tin plate, or iron in thin sheets coated with tin. Also a silvery-white cast iron.

Width (of wood): The measurement taken from edge to edge or across the grain.

Wing: The part of a divider which crosses and joins the two hinged legs near the top.

Wing divider: A divider with two steel legs hinged together. A metal quadrant attached to one leg passes through a slot in the other, and a wing bolt or set screw in the movable side is turned to release pressure on the quadrant and adjust the dividers.

Wire gage: A disc-shaped gage with holes for inserting different sizes of wire to be measured, or a gage with a V-opening, which in some cases is marked with gage numbers, decimals, and combinations of units.

Witness marks: Or reference marks, any marks made with a pencil or knife from which additional measurements can be taken, or marks drawn with a straightedge or trysquare.

Work edge: The edge made by planing smooth and straight an edge at right angles to the work face.

Working strain, safe: The amount of strain which a rope may reasonably be expected to bear safely in actual working conditions. The working strain is always considerably lower than the breaking point. It is expressed in a formula dividing the circumference squared by 9, or $\frac{C^2}{9}$ = tons.

Worming: The winding of a small cord tightly around taut rope, following the divisions between the strands. It is the first step in a process to increase rope wear.

Wrought iron: Iron with evenly diffused slag, made by puddling pig iron: it is especially suited for ornamental ironwork.

Zigzag rule: A folding rule with its sections held together by a swivel or a folding joint of metal.

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